TECHNOLOGY DEPT.

APRIL, 1943

ONE SHILLING

PUBLIC LIBRARY
SEP 7 - 1943
DETROIT

Plastics

DEALING WITH THE MANUFACTURE, USES AND POTENTIALITIES OF PLASTIC MATERIALS

British Aircraft Use

FOR QUICKER, EASIER, CABLE & PIPE LINE MARKING

DURABLE - LEGIBLE - INDELIBLY PRINTED IN ANY COLOUR
CAN BE USED WITHOUT TOOLS - RESISTANT TO FLUIDS AND HEAT

HERTS PHARMACEUTICALS LTD. WELWYN GARDEN CITY

★ No less important to the user of plastics than the adoption of X-ray inspection (either radiographic or visual or both) is the selection of suitable X-ray equipment—and demonstrably no such equipment is better suited to the special requirements of plastics radiology than the Victor "KX-140" unit. Its features of low inherent tube filtration and a penetration range from 30 kilovolts upwards are, for example, made-to-measure for the examination of light-density materials. Its remarkable fineness of effective tube focus ensures the maximum in radiographic detail. Its precision of electrical control, its facilities for continuous operations at all voltages, its shock-proof, oil-immersed construction—all contribute to a design which is functional, flexible and wholly reliable.

X-RAYS AND PLASTICS

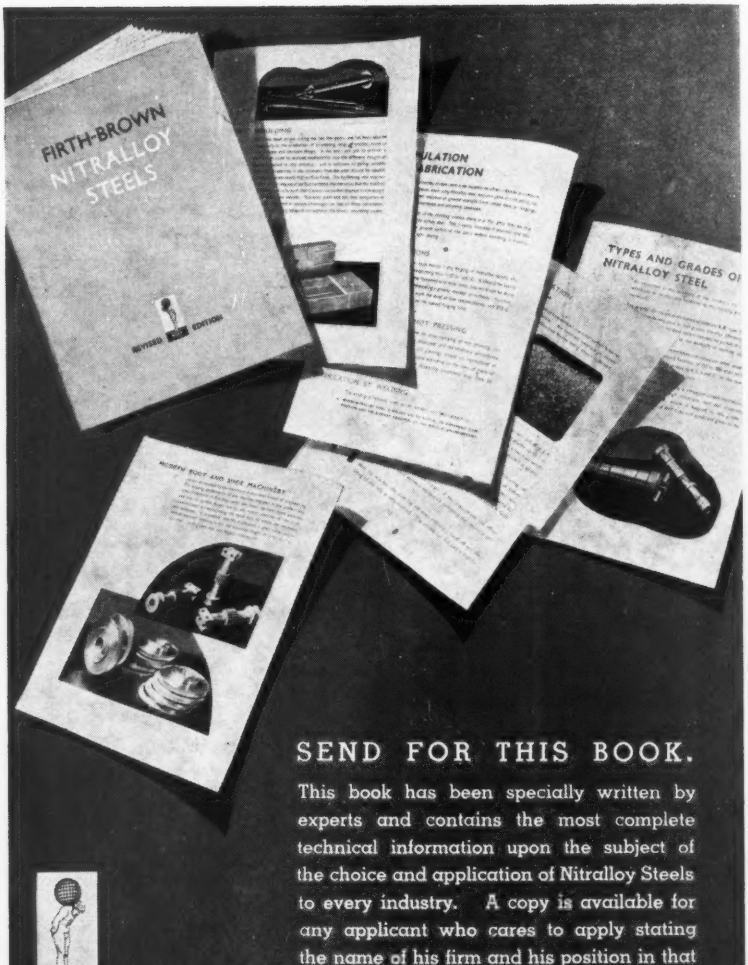
★ *Write, without obligation, to Dept. IF/3 for fuller information.*

VICTOR X-RAY CORPORATION LTD

SPECIALISTS IN THE USE OF X-RAYS IN ENGINEERING & INDUSTRIAL PROBLEMS

15 - 19 CAVENDISH PLACE, LONDON, W.1
LANgham 4074

73 Queen Sq, Bristol, 1 — Bristol 20890 55 Pershore St, Birmingham, 5 — Midland 2110
Milne Buildings, 66 Mosley Street, Manchester, 2 — Central 0275
34 West George Street, Glasgow, C 2 — Douglas 1884



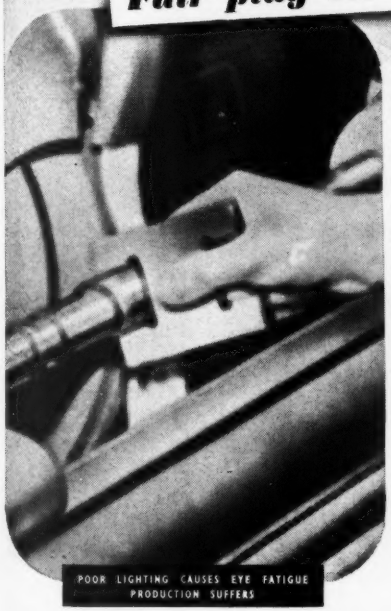
SEND FOR THIS BOOK.

This book has been specially written by experts and contains the most complete technical information upon the subject of the choice and application of Nitralloy Steels to every industry. A copy is available for any applicant who cares to apply stating the name of his firm and his position in that firm. May we send you a copy?

THOS. FIRTH & JOHN BROWN LIMITED

Fair play for the EYES

Fair play for PRODUCTION



POOR LIGHTING CAUSES EYE FATIGUE
PRODUCTION SUFFERS

DAYLIGHT
IS THE BEST LIGHT FOR THE EYES

Daylight is the natural light for the human eye and the nearer we get to daylight with artificial light the less the eyes tire. That is why the Crompton Fluorescent Tube is now being so widely adopted in industrial plants. It gives a light that is virtually pure daylight and that is almost entirely free from glare, hard shadows and reflected dazzle. The daylight quality of the light is shown by the excellent colour discrimination which it makes possible. The Crompton Fluorescent Tube is economical, too, for an 80 watt tube gives almost as much light as a 200 watt filament lamp and it lasts twice as long. By offering industry good lighting conditions throughout the twenty-four hours it makes possible an improvement in quantity and accuracy of production that is proving invaluable in wartime.

LET THE CROMPTON LIGHTING SERVICE *PLAN* YOUR LIGHTING

CROMPTON *fluorescent* **TUBE**

80 WATTS. LENGTH 5 ft.

CROMPTON PARKINSON LTD., ELECTRA HOUSE, LONDON, W.C.2

Telephone: Temple Bar 5911 *Telegrams: Crompark, Estrand, London*

Let her SEE what she's doing TO STEP UP PRODUCTION

Give your workers the lighting they deserve and they will give of their best.

ANGLEPOISE LAMPS are everywhere doing their bit for production by flooding the work with a clear, steady light that shows everything up.

Note how it gets down on the job . . . right *on* the job . . . neither in the operator's way nor glaring in her eyes. Any angle or position taken — *and held*. Can be shifted anywhere at lightest finger-touch. Never sags, never droops but "stays put."

Really economical—a 25-watt bulb works like a 60 as the light can be brought down so close to the job.

Ideal for drawing office or machine shop. Supplied with polished black base for fixing on wall or machine, with trolley standard or with short heavy base. *Pat. all countries.* Write to-day for informative literature.

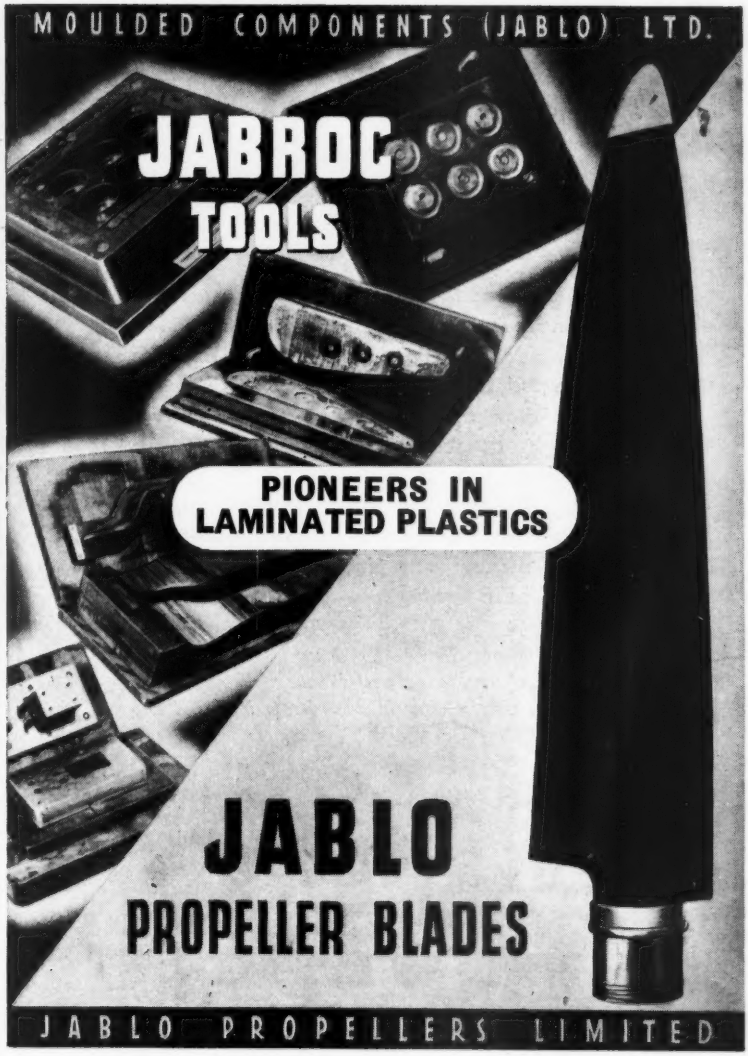
Sole Makers:

HERBERT TERRY & SONS LTD., REDDITCH

A FINGER TOUCH MOVES *Anglepoise*

The TERRY ANGLEPOISE LAMP ...the lamp of tomorrow

T.A.2


MOULDED COMPONENTS (JABLO) LTD.
JABROC
TOOLS
PIONEERS IN
LAMINATED PLASTICS
JABLO
PROPELLER BLADES
JABLO PROPELLERS LIMITED

Essex
TRADE MARK

METHYL BROMIDE

WARNING

It has come to the notice of this Company that certain statements of a damaging character have been made regarding Essex Methyl Bromide Fire Extinguishing equipment. The Company cannot allow the repetition of false statements tending to detract from its wide reputation for the manufacture of equipment of the highest quality and efficiency and hereby gives notice that legal proceedings will be taken against the persons making any such statements either verbally or in writing.

● *Owing to the priority demands of the three Fighting Services for Essex Methyl Bromide equipment it is regretted that certain delays must necessarily occur in deliveries to industrial and civil undertakings.*

The National
FIRE PROTECTION
COMPANY LIMITED RICHMOND

Fire Protection Engineers and Consultants

TELEPHONE: RICHMOND 2342-3-4

REAL ACHIEVEMENT

Sixty years ago the world was aware of a real achievement when the newly constructed Eddystone Lighthouse exhibited its beam for the first time.

Nearly sixty years before that event, the firm of Kayser Ellison was established as experts in Special Steels, and, during the long period of industrial history since that time, we have been closely associated with many great International engineering achievements. To-day the name K.E. is world famous for Special Steels for every purpose.

K·E·Special STEELS

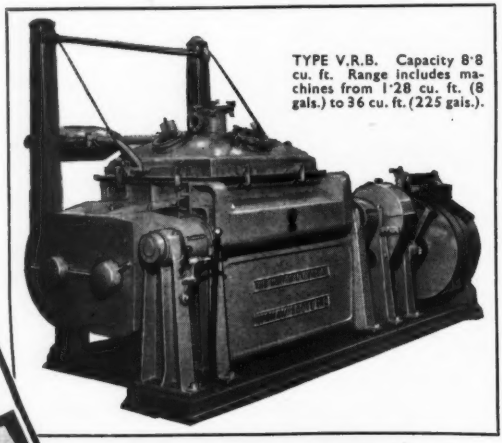
K.E. 961 and other K.E. Special Steels for Mould Die Work—in Forgings or Bars, black rolled or precision ground finish.

KAYSER ELLISON & CO. LTD.

CARLISLE STEEL WORKS, SHEFFIELD. EST. IN 1825

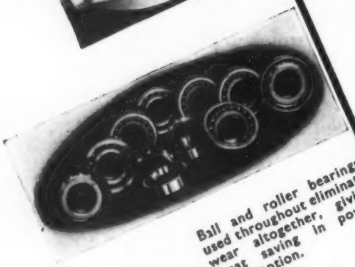
London Stockists (except for Stainless Steels):
FARMER, STEDALL & CO., 145-157 St. John Street, Clerkenwell, E.C. 1.
London Stockists for Stainless Steels:
MACREADY'S METAL CO. LTD., 131-135 Pentonville Road, London, N. 1.

Morton



TYPE V.R.B. Capacity 8·8 cu. ft. Range includes machines from 1·28 cu. ft. (8 gals.) to 36 cu. ft. (225 gals.).

The "Z" type blades, a feature of many "Morton" Mixers. Alternative and special purpose blades are fitted according to type and requirements.



Ball and roller bearings used throughout eliminate wear altogether, giving great saving in power consumption.

DUPLEX MIXERS

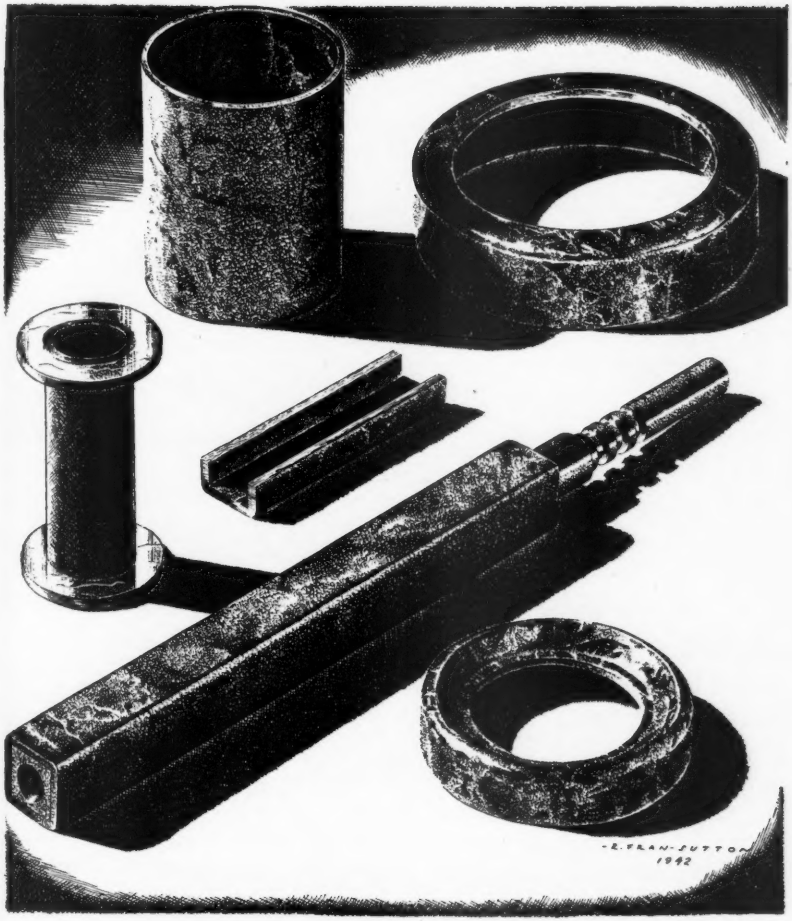
of remarkable achievement

A new design in Duplex Mixers for still greater efficiency in the mixing and blending of Plastics, Bakelite, Ebonite, Batter Compounds, Rubber Sheeting Doughs, Latex Compounds, etc. Whatever the mixing operation required, whether for doughs, heavy creams, or alternately for pulping or shredding, Morton "Duplex" Mixers are designed in a variety of models and sizes to give greater or lesser intensive action according to individual needs. Supplied for working under vacuum or steam jacketed.

MORTON MACHINE COMPANY LIMITED

1 BRIXTON ROAD · KENNINGTON · LONDON · S·W·9

TELEPHONE RELIANCE 3609



EAST LONDON MICA WORKS

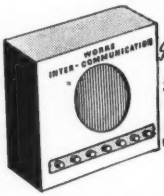
Ringwood Road, London, E.17

'Phone: KEYstone 4254 · 'Grams - Elmicmer, Phone, London.

ELECTRICAL INSULATION IN MICA & MICANITE

KENT MOULDINGS
PROPRIETORS: KOLSTER-BRANDES LIMITED
FOOTSCRAY KENT
TELEPHONE FOOTSCRAY 1195

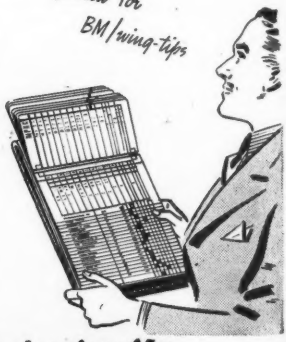
RECORDS COST MONEY — ARE YOU PAYING TO HIDE VITAL FACTS?



Is job M706 behind schedule....
Is there a reliable alternative supply...
What is our present stock of XY parts...
Total man-hours required for BM/wing-tips

Shannon Visible Records give a panoramic view of Key facts —posting is many times faster than in books. A unique all-metal Suspension holds the cards securely yet gives maximum freedom of movement. Cards are instantly removable. Both sides of the cards are available for posting and Auxiliary Sheets provide additional information or increase the card life. Let us show you how Shannon Visible Records will help to increase your control and production.

To comply with Paper Control Order 48 please send 1d. postage stamp for booklet.



THE Shannon LIMITED VISIBLE RECORDS

Give all the answers-instantly

IMPERIAL HOUSE (Dept. E.3), 15-19, KINGSWAY, LONDON, W.C.2
And at Birmingham, Bristol, Liverpool, Manchester, Newcastle, Glasgow (Agent)

FOR LAMINATED PLASTICS

New Fields

In industry, the application of Ferobestos, the hard-wearing laminated plastic, is endless in its variety. Consider its unique qualities, and the wide and new purposes which it can serve are then apparent. Ferobestos does not swell in water. Used for bushes or gear wheels it can be lubricated either by oil or water (special grades are supplied for dry running). It also can be used at high temperatures and is chemically resistant to all but the strongest acids and alkalis. Our technical department will gladly collaborate in new developments. May we supply further particulars ?

FEROBESTOS

(REGISTERED)

Plastic Products

MADE BY FERODO LIMITED. CHAPEL-EN-LE-FRITH

Two recent CELLON *developments*

LETHANE OIL

N-butyl carbitol thiocyanate 6.25%
β-thiocyanoethyl laurate 18.75%
Refined Mineral Oil 75%

A NEW SPECIFIC FOR THE CONTROL OF THE HEAD LOUSE

A field in which the new organic thiocyanates are pre-eminent on account of their low toxicity, lack of odour, non-inflammability and trouble-free application.

PROTECTIVE HAND CREAM (No. 1)

Possessing anti-dermatitis properties. Materially reduces the risk of many irritant skin troubles which develop on the hands in various industries where oil, grease, paint and other grime is unavoidable. The cream fills the pores and forms a protective layer. An invaluable preparation for use by industrial workers in Aircraft, Engineering, Ship-building and kindred industries.

FURTHER INFORMATION, SAMPLES AND PRICES UPON REQUEST

KINGSTON-ON-THAMES
Telephone : KINGSTON 1234 (5 lines)

CELLON

CELLON LABORATORIES LIMITED

ONE OF THE CELLON COMPANIES

CVB—X3

Vol. VII. No. 71 APRIL, 1943

Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

Proprietors - - TEMPLE PRESS LIMITED
Managing Director - ROLAND E. DANGERFIELD

Editor - M. D. CURWEN, B.Sc., A.I.C.
Offices - Bowling Green Lane, London, E.C.1

CONTENTS

	Page
Editorials	140
Plastics for Gears, by D. Warburton Brown ..	143
Acid Carrying Bucket ..	151
Classification of Plastics ..	152
Welding of Thermoplastics	154
Saran Tubing	159
World's Industry Employs Plastics	160
Plastic Film and Sheet for Small Coil Insulation, by E. E. Halls	162
Production News	171
Resinoids and Other Plastics as Film Formers, by B. J. Brajnikoff	173

NOTICES

All instructions, matter and passed proofs for all kinds of advertisements must reach the Head Office of "PLASTICS" by the 24th of each month to ensure insertion in the following month's issue.

TERMS—Monthly accounts, strictly net; due when rendered.

"PLASTICS" is published in London, England, at the beginning of each month.

Head Offices:
Bowling Green Lane, London, E.C.1.
Inland Telegrams - - *"Pressimus, Smith, London."*
Cables - - - - - *"Pressimus, London."*
Telephone - - *Terminus 3636 (Private Exchange).*

Midland Offices *(temporary)*: 241, Warwick Road, Kenilworth, Coventry.
Telephone / *Telegrams* } *Kenilworth 415*

Northern Offices—Manchester: Deansgate House, 274, Deansgate.
Telephone—Blackfriars 5038-9.
Telegrams—"Presswork, Manchester."

SUBSCRIPTION — "PLASTICS" will be mailed regularly to any address in the United Kingdom or abroad for—Twelve issues for 13s., post free; pro rata for fewer numbers.

SAVE PAPER

More than ever is paper waste required for our war industries. Waste paper makes munitions in a hundred forms—from shell cases to aeroplane parts.

The fact that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

EDITORIALS

Progress in Aircraft

THE news recently given in a well-known Sunday paper that a plastic-bonded "cargo ship of the air" had been built, keeps very much alive the world-wide interest in laminated plastics.

The aeroplane in question is the new American Curtiss-Wright Caravan, to be used solely for transport purposes. It is a twin-engined monoplane designed to be cheap, and easy and rapid to build. Compared with aircraft used strictly for war purposes its cruising speed of 140 m.p.h. is low, but its value is certain in transporting large loads over difficult country.

In this country much research is also being carried out in the use and shaping of resin-bonded wood veneers, but since it is all directly connected with war-craft in one shape or another, nothing has leaked out for general consumption. Doubtless the fuselage of the now famous Mosquito has been bonded with a resin.

It is certain that research and, indeed, much semi-scale work on this subject is being carried out in almost every country. Improved strength, waterproofness, rapidity of fabrication and the possibilities in the use of simple moulds and low pressure, make such methods attractive.

The low-pressure method of curing such structures, generally utilizing rubber bags with pressures from 20-200 lb. per sq. in., would appear applicable to the production of many peace-time units. It has already been suggested for the manufacture of certain types of radio cabinet and other simple shapes.

It is also interesting to note that cold-setting resins have been employed to impregnate fabric and that a new thermo-setting, transparent resin, which cures without evolution of water and is, therefore, amenable to low-pressure curing and moulding, has been evolved. Its chemical identity has not yet been divulged, and it is known only under the trade name of Columbia Resin 39 (see Kline, "Modern Plastics," Jan., 1943). It would seem to answer some of Mr. Bridge's requirements during the recent famous Plastics Brains Trust Session, not only for normal moulding but also for building laminated structures.

Synthetic Rubber

SOME few years ago we gave it as our opinion that while synthetic rubber would always be in demand in special markets, it was improbable that the price of the synthetic compound could ever be as low as that of natural rubber. It would seem that we may yet have to eat our own words. Mr. S. Moos, in the Institute of Statistics (Oxford) Bulletin, reveals some startling figures that have been obtained from the United States.

There seems little doubt that a price of about 25 cents per lb. is now a fair one for the industry to produce at, and it has been declared that this may even be lower, say, 22 cents. When we consider two things, one, that the price of natural rubber in 1939 was 21 cents in the U.S.A. at the outbreak of war and, two, that those of synthetic rubbers between 35 cents to $1 at the end of 1940, we can realize the tremendous reduction in production costs.

What chance, then, has natural rubber to come into its own when the plantations get going, and who can say that the synthetic cannot be even cheaper than it is? It is true that during the "bad times," the natural material dropped to about 2d per lb., which was apparently quite uneconomic. What a fair price for it is has never really been made clear, but doubtless there will be a big effort to improve plantation rubber by several means, for example, the production of new strains to give increased yields, by new

tapping methods, etc. It is stated that 1,000 lb. could thus be collected where only 400 lb. are now produced.

It has been put forward in these pages and elsewhere, that by research natural rubber will one day be made as resistant to oils and ozone as synthetic rubber. This is probably true, but to compete with the latter on such properties it would be essential for the raw rubber, before it is converted, to be much cheaper than synthetic.

Classifying Plastics

ON another page in this issue we publish some notes by Mr. W. S. Stevens, the well-known rubber technologist, regarding the classification of plastic raw materials.

Of the necessity of distinguishing between the various materials of our industry there is no doubt. It is not a mere academic necessity, but one of importance for clarifying our own minds on the point and also the minds of the layman or industrialist who knows little about them. Confusion may have a strong effect in refusing to consider their individual merits or demerits.

Mr. Stevens's classification, therefore, is very welcome. It is the first we have published, and since both it and the author are elastic and elastic-minded, we presume it is not absolutely complete.

His segregation is into five groups: Addition Plastics, Co-polymer Plastics, Condensation Plastics, Natural or Modified Natural Plastics and Plasticizers, so that on the whole it would appear to be a chemical classification. That is, it is based on the manner in which the plastics are formed from simple units into large molecules.

This is certainly one clear method of doing it, and were the plastics industry a purely chemical one and if it did not interest the layman, we think the classification sufficient as it stands. But the plastics industry is chemical in only one aspect of it and the layman is vitally interested, as Mr. Stevens knows. Moreover, people are more interested in how to manipulate plastics and what they feel and look like than in their chemical composition. The fact that one plastic will stand up to 120 degrees C. while another will not is tremendously more important to an engineer than knowing that one is a co-polymer and another is a condensation product. In other words, we feel that the older classification of thermoplastic and thermosetting types is still very important and somehow should be included in the scheme. The fact that there would be some overlapping, as Mr. Stevens rightly points out, is not insuperable.

As for the inclusion of Group 5—Plasticizers—no doubt there will be some criticism. They are not plastics, as the author admits, but they are used in all thermoplastics, often in very large proportions, and help to improve or modify the properties greatly and also aid in moulding and extrusion processes. A pedant, however, might point out that wood flour, fabrics and even colours should then be added to the list.

NEW BOOKS

Synthetic Resins and Allied Plastics

By various authors. Second Edition, edited by R. S. Morrell, M.A. Pp. 580. Oxford University Press (London: Humphrey Milford, 1943). Price 35s. net.

Since 1937, when the first edition appeared, progress in the development of plastics has so rapidly increased that, as Dr. Morrell admits, the discussion of the whole subject cannot now be made adequately by the four contributors who subscribed to the first edition. The contributors to the present volume are:—R. S. Morrell (one-time Chief Chemist to Mander Bros. and now Hon. Research Tutor, Wolverhampton and Staffordshire Technical College), J. R. Alexander (W. Walker and Sons, Ltd., Bolton), E. A. Bevan (Beck, Koller and Co., Liverpool), R. P. L. Britton (Hadfields, Ltd., Mitcham), E. G. Couzens (BX Plastics, Ltd., Manningtree), Rowland Hill (I.C.I., Ltd., Manchester), H. M. Langton (Consulting Chemist), H. S.

Lilley (I.C.I., Ltd.), C. A. Redfarn (Consulting Chemist) and V. E. Yarsley (Consulting Chemist).

The new volume is, without doubt, the most comprehensive chemical treatise yet published in this country of the raw and finished materials that are utilized by the plastics industry.

In his ably written General Introduction, Mr. Langton gives us the story of the origin of each plastic or synthetic resin, makes a good picture of the raw materials on which they are based and of the different plastics which result from them. The chapters that follow are, in a sense, elaborations of this introduction.

Protein and cellulosic plastics are dealt with by Mr. Yarsley in one chapter, and in it are included casein, a timely section on soya-bean and soya-bean resinoid plastics, nitrocellulose, cellulose acetate and aceto-butyrate and the ethers under which are included methyl-, ethyl- and benzyl-cellulose. The solvation and plasticization of the cellulose compounds are discussed and the manufacture of plastics from them are adequately described by reference to sheet rod and tube production, film formation and injection moulding.

The same general scheme is devised for most of the remaining chapters. Redfarn deals with both phenol and urea-formaldehyde in two separate sections which prove to be the most detailed and comprehensive of the whole book. His treatment of the raw materials necessary for production, the theory of formation of these resins, the commercial production of moulding powders and of the moulding operations and of simple mould design is excellently done. Moreover, all this is amplified by a section dealing with the testing of phenolics according to B.S. Specifications.

Vinyl and acrylic resins are in the able hands of Rowland Hill. While these sections are admirably complete from the chemical point of view, it is to be hoped that at some future date they will be expanded to emulate Redfarn's sections by the inclusion of some of the methods of fabrication by moulding, shaping or blowing and of welding.

One of the most important and useful of the chapters is that by R. P. L. Britton, which deals with electrical testing and requirements. This section not only deals with the better-known synthetics, but also the natural resins and bitumens and resin-oil varnishes.

The problems of resinification are admirably dealt with by Morrell, and Couzens completes the book with a chapter on the methods of identification and testing of synthetic resins and other raw materials of plastics. This last is most important to all chemists in the industry.

We have no hesitation in welcoming this new edition, in many ways an entirely new book and probably the best of its kind so far written. There is some overlapping, as is usual with a book written by a number of different writers, and, as we have already indicated, we ourselves should have preferred Redfarn's methods carried out by some of the other contributors. But the excellence as a whole remains, and the editor and his co-workers are to be congratulated.

Plastics in the Home

By V. E. Yarsley and E. G. Couzens. Published by J. M. Dent and Sons. Pp. 31. Price 6d.

Many of our readers will have read some, if not all, of the "Design for Britain" series which have appeared in the past year or so. Building and architecture is strongly represented in this series, so that the recent addition to it of "Plastics in the Home" is not surprising. The same two writers of the Penguin best-seller "Plastics" have repeated their success in a simply worded and carefully conceived description of the materials of our industry. The general public and, we hope, the building industry will thus obtain a good view of the many units that compose the plastic family, their properties and methods of manipulating them.

Plastics for Gears

Concurrent with the acceptance by Industry of resin-fabric gears has been the study of their design and fabrication methods

By D. Warburton Brown, A.M.I.A.E., M.I.P.I.

FOR many years engineers have realized the advantages which are offered by the quiet operation of gear drives, and in more recent years, with the advent of modern high-speed machinery, this aspect of gear drives has assumed a new importance. It has long been realized that the introduction of gears manufactured from non-metallic materials will reduce the noise emission from transmission gear trains to a minimum. The earliest material of this type which was used was rawhide, and although it functioned fairly satisfactorily from a mechanical point of view, it suffered from a number of serious defects. It was found, for example, that if gears manufactured from rawhide blanks were left in store for any length of time distortion and cracking occurred in the material.

The Development of Plastic Gears

It was not long after the introduction of the laminated phenolic plastics that engineers realized that these new materials might well be an answer to their problems in connection with silent gear drives, and a number of practical tests confirmed this. The earlier forms of laminated plastics had limitations, but in view of the excellent promise shown in initial tests, a great deal of material research was carried out by the plastics industry with a view to meeting the requirements of engineers. Now there are several grades of phenolic laminated material which have been specially developed for the manufacture of silent gear wheels. The importance which is attached to the use of plastics for gears is reflected in the fact that there is now an official material specification laying down the minimum strength requirements for plastic materials used for this purpose.

There are a great number of gear drives where the use of high-tensile steels is not necessary, and in many cases it is not economical to specify gears cut to high precision limits. In such cases laminated plastic materials may be considered with advantage. These materials can be used to produce all types of gears, and the prospective user should consult the material manufacturer regarding the best grade of plastic to use for the conditions of power and service under which the gears in question will be called upon to operate.

Very briefly, the advantages claimed for these types of materials are that, structurally, they possess a toughness which is unusually high for organic substances, resulting in excellent wearing properties, they are unaffected by oil, water, steam and many chemicals. This latter property makes them eminently suitable for pump gears used by the chemical industry for pumping acids and other corrosive substances which would readily attack metal gears.

The silent-running properties of plastic gears has led to their wide adoption in factory drives of all sorts since the fatiguing effects of noise upon the employees has been realized by industrial psychologists, and works engineers have been quick to adopt means of reducing factory noise to a minimum.

Raw Materials for Fabrication

It has already been pointed out that the materials used for the manufacture of plastic gears are the fabric base laminated phenolics. These types of materials are

produced by impregnating sheets of fabric with an alcoholic solution of phenol-formaldehyde resin, and forming these sheets under heat and pressure into thick sheets, tubes, or rods. Careful tests are made during the manufacture to ensure that the correct amount of resin is retained in the fabric, and to ensure that the properties of the finished material will be uniform.

There are several grades of laminated phenolics which are suitable for gear manufacture, the main difference in these being the mesh of the fabric. For example, it has been found that for small mechanisms, such as clockwork motors, it is desirable to use a material having a fine-weave fabric base. In this manner the maximum amount of fabric is incorporated in each tooth, a feature which is very desirable when dealing with small gear teeth. For general purpose and large drives, however, a coarser type of fabric can be used quite satisfactorily. Apart from these two main classifications, there have been a number of special grades of material developed for gears called upon to operate under extraordinary conditions.

The laminated plastics used for gear work possess exceptionally good mechanical properties for materials of this type, and are also sufficiently resilient to absorb intermittent stresses and shock loads without suffering damage. This natural resiliency of the material enables very quiet drives to be obtained. The physical properties of typical fine and coarse mesh fabric base materials are given in Table 1.

Design Considerations

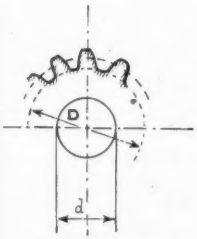
In order that the best results shall be obtained when using plastic gears it is necessary to take into consideration the peculiar properties of these materials and to adhere to certain general design rules. It is also desirable that the methods of installing the gears should receive special attention.

Overload

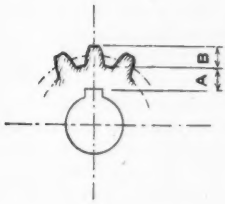
In nearly all cases where gear trains are used the teeth become subjected, for one reason or another, to loads in excess of the nominal rating, and it is necessary to make the gears sufficiently strong to transmit at least 25 per cent. in excess of the rated horse-power. When the drive is subjected to a known overload the gear must be capable of withstanding 25 per cent. in excess of the maximum overload. In cases where the gears are likely to be subjected to heavy shock loads, such, for example, as in crushing machinery, the safety factor is made considerably greater—in some cases such gears are designed to accommodate as much as 2½ times the rated load.

Table 1.—Properties of Phenolic Laminates Suitable for Gears.

	Coarse fabric base (general purpose)	Fine fabric base (small gears)
Specific gravity	1.34	1.37
Specific vol. (cubic in./lb.)	20	20
Wt. per cubic in. (lb.)	.05	.05
Tensile strength (lb./sq. in.)	9,000	11,000
Mod. of elasticity (lb./sq. in.)	550,000	650,000
Mod. of rupture (lb./sq. in.)	18,000	25,000
Compressive strength (lb./sq. in.)	43,000	46,000
Shear strength through laminæ (lb./sq. in.)	12,000	14,000
Water absorption	.7%	.7%
Oil absorption	under .1%	under .1%



D must not be less than 2 × d.



A must at least equal 1½ × B.

Fig. 1.—Proportionate dimensions of plastic gears.

Pitch Line Velocity

In view of the lightness of plastic materials pitch line velocities can be high, and for general applications a maximum of 3,000 ft. per minute should be adhered to. If the gears are rigidly mounted and supported on each side it is permissible to increase this to as much as 5,000 ft. per minute.

When the pitch line velocity exceeds 750 ft. per minute, however, it is not practicable to use pinions with less than 18 teeth. If it is essential to have more teeth in pinions working at high velocities, special attention must be given to the design of teeth and the form modified in order to avoid interference.

Dimensions of Gears

When designing gears in plastic materials the diameter of the whole depth circle must not be made less than twice the diameter of the bore. If it is necessary to incorporate a keyway in the bore, the distance from the root of the tooth to the top of the keyway slot should be at least one and a half times as great as the full depth of the tooth. (Fig. 1.)

In connection with the subject of keyways it is sometimes advisable to fit metal bushes to the gear. This applies particularly when the dimensions of the key are small, or when taper fits are called for.

In gearing of all types interference is likely to occur if the tooth proportions or number of teeth are unsuitable. It is particularly important that this phenomenon should be divided when using plastic gears if efficient operation is to be obtained. The elastic nature of plastics tends to accentuate interference, particularly in pinions having less than 18 teeth. It has been found that in gears having a small number of teeth it is advisable to use a 20° pressure angle as this form of tooth does not give as great an interference as the 14½° form. As has already been pointed out it may be necessary to modify the tooth form by altering the addendum and dedendum up to a maximum of all addendum when using gears with less than 18 teeth.

Plastic gears should always be meshed with metal gears, and both the driver and driven gears should have machine-cut teeth if smooth and silent operation is to be obtained. The width of the metal gear should always be equal to or greater than that of the plastic pinion. It should never be less, and if there is any side float on either of the gears, an allowance should be made so that at no time can the plastic pinion over-ride the mating metal gear.

It is necessary to allow a certain amount of backlash between two mating gears in order to allow for machining errors in the tooth form or shaft centres. For general purposes a backlash of .030 in. to .050 in. is accepted as being suitable for gears of 1 diametral pitch, and proportionately for gears of other pitches.

Although it has been stressed that plastic gears should always run meshed with metal gears, it is possible in certain cases where anti-corrosive materials must be used throughout (e.g. in pumps for the chemical industry) to run two plastic

gears in mesh. When this is necessary special consideration must be given to the conditions under which the pinions will be called upon to operate.

If it is necessary to protect the end faces of the plastic gear or to increase the strength of the keyway, metal shrouds may be fitted. Shrouds are not essential, but if fitted for the purposes outlined above they do increase the power transmitting capacity of the pinion by about 5 per cent. (See Fig. 2.)

If the plastic gear will be required to run immersed in hot oil, or if it will be exposed to an atmosphere of damp heat, it is advisable to give the plastic material an oil-conditioning treatment. This conditioning consists of soaking the gear in oil at 90 degrees C. for a period of 100 hours before the finish machining operations are performed.

Machining of Plastic Gears

The laminated phenolic plastics, such as are used for the manufacture of non-metallic gears, can be machined in much the same way as metals, but experience is necessary if frayed edges are to be avoided. The nature of the material must be kept in mind—especially when threads or intricate shapes are being machined.

No special equipment is necessary for machining these laminated materials and, in general, they can be turned, milled, drilled, tapped and shaped on the same machines as are used for performing these operations on metals.

The action of laminated plastics on the cutting edges of tools is highly abrasive and it is essential that cutting edges of all tools should be kept very keen. If blunt tools are used the finish will be ragged and overheating and burning of the material will result. Because of the highly abrasive nature of the material, carbon steel tools are not employed for machining laminated plastics, and high-speed tool steel is usually considered satisfactory. When specially high finishes are required, diamond or tungsten carbide tools give the best results. It is not necessary, in the majority of cases, to use a coolant, but an air blast is beneficial for keeping down the temperature of the tool. When it is found necessary to use a coolant, thin oil or soapy water gives satisfactory results.

Another important point to be borne in mind when machining phenolic laminates is that the tool should always be kept clear of swarf. This applies particularly when drilling and tapping blind holes, and is also important when sawing, when a clogged saw would have an adverse effect upon the quality of the work.

It is advisable to keep special tools for machining plastics, since the rake and clearance angles which give the most satisfactory results can thus be utilized. Details of the best tool forms to use are given later in this article.

Drilling

Drilling of the laminated plastics may be carried out on any standard type of drilling machine, but if small-diameter

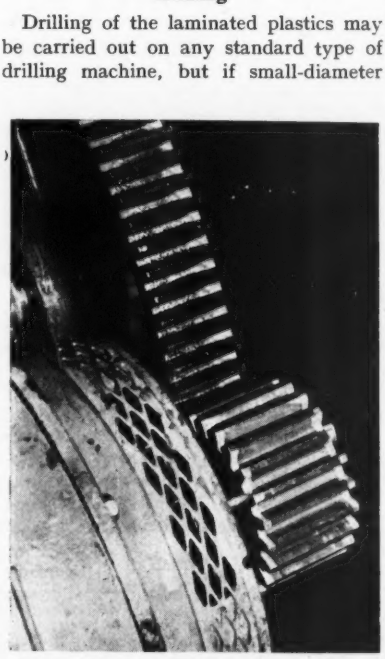


Fig. 2.—Gear drive using shrouded plastic pinion.

holes are necessary it is advantageous to use a high-speed drilling machine.

To obtain the best results, it is desirable that the drills used should have the following features:—

(1) The included angle of the point should be between 50 degrees and 60 degrees.
(2) A slow angle of twist or helix of the flutes.
(3) The flutes should be as wide as possible and have a long lead.
(4) The lips should be ground thin and given little rake.

It is possible to obtain drills embodying these features from many of the well-known drill manufacturers. If these points are observed the operation will be speedier and cleaner, and there will be little tendency for the swarf to clog the flutes and thus cause overheating.

It is important, especially when drilling deep holes, to withdraw the drill at least every ½ in. of feed. By so doing, the tip is cooled and the swarf is allowed to get away. A blast of air materially assists in cooling the drill and clearing the hole.

When drilling holes the direction of which is parallel to the laminations in the material, the angle of the point should be modified to give an included angle of 118 degrees. (See Fig. 3.)

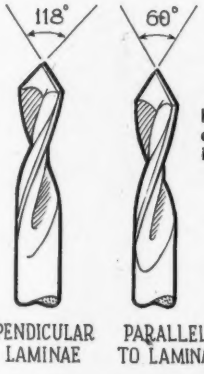


Fig. 3.—Type of drills for working laminated plastics.

Recommended drilling speeds are given in Table 2.

Table 2.—Recommended Speeds for Drilling Laminated Plastics.

Diameter of drill	Drill speed (r.p.m.)
Up to ⅛ in.	1,500-1,000
⅛ in. to ¼ in.	1,000-800
¼ in. to ½ in.	800-600
½ in. to 1 in.	600-150

When holes of 1-in. diameter or greater are to be machined, it is recommended that the work should be mounted in a lathe and a boring bar used.

In order to avoid ragged edges to the holes where the drill breaks through, the plastic should be firmly clamped to a piece of hard wood or to another piece of laminated plastic sheet prior to drilling. This prevents separation of the laminæ as the point of the drill breaks through.

Turning

Laminated plastics with a fabric base such as are used for producing " silent " gears can be turned quite satisfactorily on lathes used for turning metals, but certain precautions are necessary in the grinding of the tools.

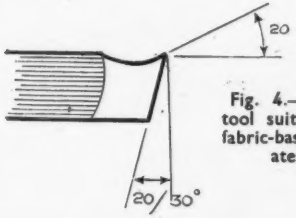


Fig. 4.—Turning tool suitable for fabric-base laminates.

On the subject of tools, it has been found that a high-speed steel gives excellent results, but where extra high finish is desirable a " Wimet " or " Stellite "-tipped tool, or preferably a diamond tool should be used.

The makers of the various grades of laminated gear materials all issue machining instructions for their own particular brands, but as these vary considerably, it is advisable to consult the makers of

the material as to the most satisfactory machining methods.

This will be appreciated when it is pointed out that two makers of fabric-base laminates give the instructions shown in Table 3:—

Table 3.

	Type A	Type B
Cutting speed ..	400–600 f.m.p.	600–1,000 f.p.m.
Cut	$\frac{1}{64}$ in.–$\frac{1}{8}$ in.	fine feed
Top rake on tool ..	nil	20–30°
Clearance angle ..	10–12°	12–14°
Cutting angle ..	20°	20–30°

In general, however, fabric-base laminates can be given a high-turned finish if the manufacturer's recommendations are adhered to, and the swarf will come away without undue dust.

When it is desirable to produce a number of identical gear blanks, these can

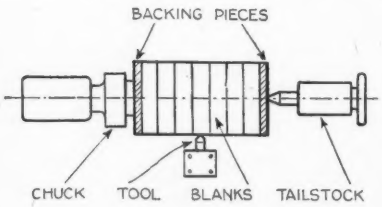


Fig. 5.—Turning "banks" of identical gear blanks.

be turned in a "bank" as shown in Fig. 5. When this is done it should be remembered that a piece of hard wood, or another piece of laminated plastic, should be used to back up the "bank" in order to avoid ragged edges when the tool feeds out beyond the last blank.

Tapping

When tapping laminated plastics the tap must be kept very sharp if satisfactory results are to be obtained. This is essential. Tapping can be carried out by hand or by machine, and strong threads are obtained because the grain of the material runs parallel to the threads.

It is advisable to countersink the tapping hole before tapping. This precaution eliminates the possibility of the laminæ "lifting" or separating when the tap enters the hole. (See Fig. 6.)

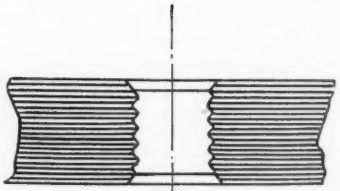


Fig. 6. — Countersinking tapped holes in laminated plastics.

When it is necessary to drill holes in the direction of the laminæ (that is in the edge of a sheet) the tapping drill should be a little larger than normal, and the material should be clamped in a vice during the tapping operation to prevent delamination occurring. The use of a slightly oversize tapping drill is also recommended when tapping blind holes.

Data for tapping holes from 4BA to $\frac{1}{2}$-in. Whitworth on a capstan lathe, and using taper taps, are given in Table 4:—

Table 4.

Operation	Speed
Drilling	900 r.p.m.
Tapping	200 r.p.m.
Clearing up	750 r.p.m.

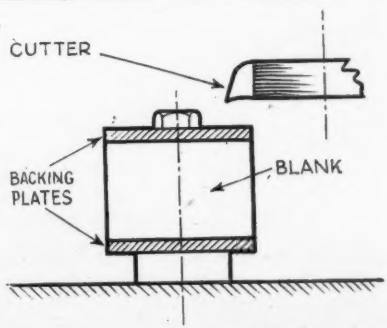


Fig. 7.—Use of backing plates during shaping operations.

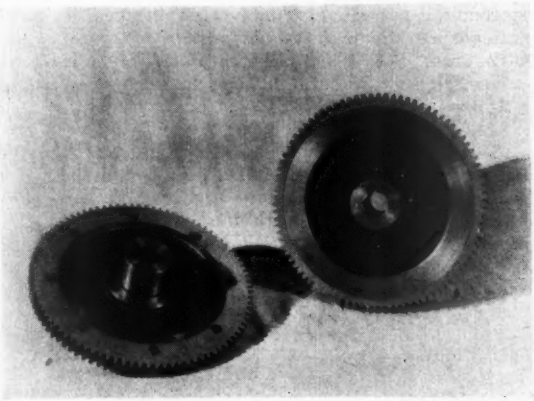


Fig. 8.—Plastic gears with steel bosses.

The use of three-fluted taps gives better clearance for swarf to get away, but provided the tap is kept sharp perfectly satisfactory results can be obtained with standard four-flute taps.

Gear Cutting

Gears manufactured from laminated plastic materials may be machined on any machines which are normally used for cutting metal gears, such, for example, as gear shapers, hobbing machines and milling machines.

When unshrouded blanks are being cut the blank should be firmly clamped between two discs of hard wood, or brass, in order to prevent delamination occurring when the cutter passes over the edges of the blank. If this precaution is taken teeth with perfectly clean edges will be obtained. Discs cut from scrap pieces of laminated material can be used equally well for this purpose. Fig. 7 illustrates this point.

If several identical gears have to be made they can be cut in "banks," and in this case it is only necessary to provide backing discs at each end of the "bank."

Generally speaking, unshrouded gears are best cut dry, but when metal shrouds are employed it is advisable to use a lubricant, such as a light oil.

When using gear-shaping machines of the Maag or Fellows type the usual cutters can be used satisfactorily pro-

Fig. 9.—Another example of a gear drive employing a shrouded plastic pinion.

vided they are kept in a sharp condition. On such machines the operating speed should be in the region of 100-125 strokes per minute, but whenever possible a high-speed head working at 500 strokes per minute should be used. If a high-speed head is employed the feeds should be fine.

Hobbing machines of the Barber and Coleman type can be used for machining plastic gears, and the standard hobs are satisfactory provided that they are kept sharp, and are used with the machine operating at a maximum speed of 300 ft. per minute. This speed should be reduced, however, if the gear is fitted with metal shrouds.

When plastic gears are to be made on standard milling machines, a speed of 350 to 400 ft. per minute should be used dependent upon the finish required.

Generally speaking the teeth of plastic gears up to 10 D.P. can be finished in one cut, but for larger gears, or when specially high finish is required, two cuts should be taken, about .005 in. being removed on the finishing cut.

[Note: The photographs are reproduced with the kind permission of Ellison Insulations Ltd.]

Plastics in Southampton

It is with considerable pleasure that we announce the inaugural meeting, in Southampton, on March 13, last, of the southern section of the Institute of the Plastics Industry.

Dr. Harry Barron, chairman of the new section, welcomed the visitors, who included the Mayor of Southampton, Mr. W. Craven-Ellis, M.P., Mr. T. L. Birrell, B.A., chairman of the Council of the Institute, Mr. R. P. Cartright and Mr. P. Smith, chairman of the London section. Members of the committee of the southern section include Messrs. O. B. H. Clark, T. Gilbertson, H. P. Grinyer and A. Macauley. Mr. G. L. Barron is honorary secretary

In his address Dr. Barron said how pleased he was that important local representation was encouraging the growth of the section.

It was the intention of the southern section to further the national welfare, and more especially as it related to the south of England, by fostering education in all its aspects of plastics development.

"We cannot deprecate too strongly the misguided and very often mischievous statements of uninformed individuals, sometimes in very high places, which seek to make our infant industry into an infant prodigy," continued Dr. Barron. "Plastics do not provide the answer to every problem. There are many materials offering a wide range of properties. It is always a question of selecting the right material for the purpose.

"But the production and expansion of these plastics must develop in an orderly manner. We want no mushroom industry. We want no speculators' boom based on the magic word 'plastics.' The only answer to this is education on plastics, which is one of our main objectives."

Speaking of the future of plastics in the south of England, Dr. Barron said he thought the prospects were very bright. "The character of their material and their commercial application are favourably influenced by our geographical location," he said. "We are at no disadvantage compared with other more highly industrialized parts of the country.

"There are already indications of almost inexhaustible outlets. For we have available a most unusual combination of strength, lightness and real beauty. Building, shipping, engineering, aircraft, motor-cars are some of the obvious markets.

"But it is useless to build extravagant hopes for materials which remain very costly. Sooner or later we must come back to a state of affairs where price may be more important than priority."

Turning to the question of raw materials, Dr. Barron said there were three main possibilities. Coal was the obvious first choice for this country. Yet coal alone, even if properly used, would not be able to meet the requirements of the plastics industry when it really got going. The second possibility would augment this. It was the manifold expansion of the petroleum-refining industry. Import of crude oil and home refining seemed right in principle and must come about.

The third possibility might have greater local appeal. The wedding of agriculture to industry was no longer a dream. More particularly the application of agricultural products to plastics was a reality as Henry Ford had proved, and as the synthetic rubber activities in America and the U.S.S.R. had shown.

The new Lorival cast resin bucket for transporting acids and solvents. It is an interesting and valuable replacement of rubber in industry.

Chemical Carrying Buckets

OF the many present problems in the chemical, tanning and electro-plating industries not the least is the increasing difficulty of obtaining rubber or ebonite buckets for the handling of acids and other corrosive liquids.

The use of the familiar rubber bucket has been almost universal in these industries, and with the imperative necessity of conserving supplies of rubber wherever possible, many chemists and works managers are wondering what substitute they can employ.

Fortunately there is a well-tried synthetic plastic bucket available which will meet many of their needs. This is the Lorival acid bucket, made from a cast phenolic resin which has been found from many years' experience to be unaffected by a number of chemicals used in various branches of industry.

Not only can the Lorival bucket be used for many of the more common acids, such as sulphuric and hydrochloric in the cold, but in many cases it remains unaffected by these liquids at much higher temperatures. This container will therefore fulfil the requirements in many establishments where such acids have to be handled in the course of manufacturing processes. Moreover, the bucket is extremely robust, having been cast to a good thickness, about $\frac{3}{8}$ in.

The Lorival bucket is already well established in many of the leading firms engaged in producing chemicals and in the applied chemical industries such as tanning, artificial silk manufacture and also in the chlorinating industry.

While it cannot be recommended for the carrying of caustic solutions the bucket can be used in many instances where its predecessor in ebonite would be unsuitable, and establishments concerned with the handling of organic solvents such as 90's benzol, naphtha, carbon tetrachloride, fatty acids and acetone, can use the Lorival bucket with every confidence. Rubber, as is well known, swells or dissolves in many organic solvents. The cast resin bucket has therefore a wide possible market.

It has been subjected to a lengthy series of tests which go to show that although with some chemical agents a noticeable discoloration of the plastic material takes place, this does not indicate that deterioration of the surface of the bucket or contamination of the contents has occurred.

The Lorival Bucket can be readily supplied in the popular two-gallon size. Full technical data are available on application to the manufacturers, United Ebonite and Lorival, Ltd., Little Lever, near Bolton, Lancashire.

Classification of Plastics

By W. H. STEVENS

THE following grouping is suggested for general usage. This scheme is based on the type of chemical reaction by which the plastic is formed and has already been presented in some detail by P. O. Powers (News Edition A.C.S., 1941, *19*, No. 13). It is here somewhat revised and offered for the use of the interested layman. All that has to be done is to remember there are three groups of synthetic plastics and one of natural or modified natural plastics.

Beyond this general classification it seems only possible at present to deal with individual products by their common, or registered trade, names. This seems preferable to attempting, as has been frequently done, to subdivide the main groups into various classes with new names such as Elastoplastics, Elastenes, etc., which usually serve to confuse the issue. The present writer feels, however, it is difficult to make hard-and-fast rules on this subject. New plastics are constantly being devised, but unless some basic new reaction is discovered it appears unlikely that the suggested grouping will require modification other than the addition of new members as they come along. Per contra, in any classification based on properties or applications drastic revision may be necessary from time to time. For instance, the recently introduced process of curing some vinyl resins would appear to take them out of the so-called thermoplastic (heat softening) class though they remain satisfactorily within Group 1.

With regard to the distinction usually made between thermoplastic and thermosetting resins it will be seen that they fall substantially into Classes 1, 2 and 3 respectively, but it is submitted that this distinction is inadequate for a general classification; for instance, there are plastics which have both properties, e.g., numerous polyvinyl resins and rubbers.

GROUP 1.—ADDITION PLASTICS

(synthetic linear polymers)

Polyethylene: — Polythene, "Alkathene."

Polyisobutylene:—"Vistanex," "Isolene," "Oppanol."

Polyvinyl alcohol:—"Resistoflex."

Polyvinyl acetate:—"Gelva," "Vinylite A," "Vinaplas," "Mowilith."

Polyvinyl chloride: — "Koroseal," "Welvic," "Chlorovene," "Korvic," "Vinylite Q," "Koran," "Mipolam."

Polyvinyl acetals:—"Alvar," "Formvar," "Butvar," "Saflex," "Vinylite X," "Bexone F."

Polyacrylates:—"Perspex," "Lucite," "Acryloid," "Plexiglas," "Crystallite," "Portex," "Callodent," "Plexigum."

Polystyrene: — "Lustron," "Distrene," "Styron."

Coumarone resins:—"Cumar."

Polychloroprene: — Neoprene, "Sovprene."

Polybutadiene:—The numbered "Bunas" (such as Buna 85) and the Russian "SKA," "SKB."

The above plastics are described as linear polymers, as they are formed by the joining together of the individual molecules, or monomers (all alike) to make long chains. These long-chain molecules are relatively free from one another, which results in the products being thermoplastic to a varying degree, although recently it has been found that some of the resins with suitable structures (side groups attached to the long chain), such as polyvinyl acetals, can be made heat curable. It is thought that in this process, as in the vulcanization of rubber, the long molecules become joined together by cross links which results in the change of properties associated with curing processes. Similarly, the polychloroprene and polybutadiene chains can be cross linked (vulcanized)

by virtue of their inherent structure (residual double bonds). Even polyvinyl alcohol can be vulcanized with sulphur.

GROUP 2.—COPOLYMER PLASTICS

(synthetic linear mixed polymers)

This group is similar to Group 1, but the long chains are formed from two or more different monomers, hence the name copolymers, because they are polymerized together. The group includes the more important synthetic rubbers, except "Thiokol" and Neoprene.

Poly-butadiene/styrene:—"Buna S," American GSR ("Buton" S, "Chemigum" IV, "Hycar" TT, "Hycar" OS-30, etc.)

Poly-butadiene/acrylic nitrile:—"Buna N," "Perbunan," "Hycar OR," "Thiokol RD," "Chemigum I."

Poly-vinyl acetate/chloride:—"Vinylite V" (and others as under p.v.c.).

Poly-acrylate/methacrylate: — "Acryloid."

Poly-isobutene/butadiene: "Butyl A."

Poly-isobutene/isoprene: "Butyl B."

Poly-vinylidene chloride/vinyl chloride:—"Saran."

GROUP 3.—CONDENSATION PLASTICS

(synthetic condensation polymers)

Phenolic resins: — "Bakelite," "Mouldrite," "Rockite," "Durez," "Nestorite," "Catalin," "Beckacite," "Epok," "Phenoglaze," "Resinox," "Opalon."

Urea resins:—"Beetle," "Mouldrite," "Plaskon," "Beckamine."

Melamine resins:—"Melmas," "Plaskon."

Aniline resins:—"Panilax."

Polysulphides (thioplasts):—"Thiokol" A, A/Z, F, and FA, "Ethanite," "Novoplas A."

Polyesters:—"Glyptal," "Paraplex," "Paralac," "Amberol," "Beckosol," "Vulcaprene."

Polyamides:—Nylon.

This group includes the thermosetting resins, the polysulphides, Nylon and various paint resins. All formed by a condensation reaction (elimination of water) as opposed to straight addition of unit molecules as in Groups 1 and 2.

GROUP 4.—NATURAL OR MODIFIED NATURAL PLASTICS

Polyisoprene:—Natural rubber.

Rubber derivatives:—Rubbone, "Pliofom," "Pliofilm," "Marbon," "Vulcalock," "Alloprene."

Cellulose derivatives: — "Celluloid," "Nitron," "Xylonite," "Bexoid," "Rhodoid," "Fibestos," "Cellomold," "Lansil," "Celastoid," etc. Ethyl rubber (plasticized ethyl cellulose).

Casein:—"Erinoid," "Lactoid."

Bitumen.

Shellac.

Rosin (colophony).

Modified rosin:—"Albertol," "Beckacite."

(Of all plastics, natural rubber has been used to the greatest extent hitherto and its production and use at a rate well over a million tons a year has exceeded the tonnage of all other plastics put together. War developments will undoubtedly affect this state of affairs.)

GROUP 5.—PLASTICIZERS

These materials are included here because they are used with plastics for promoting flexibility, etc. They are not polymers and should not be confused with plastics. Usually they are liquid or semi-liquid. Examples are dibutyl phthalate, diethyl phthalate, tricresyl phosphate, methyl ricinoleate, dibutyl sebacate, "Santicizers," "Reomols," "Aroclors," "Sextone," etc.

Trade Names

Numerous trade names have been included in order to make the classification as helpful as possible. However, the accuracy of these cannot be guaranteed, and suggestions for improving the list will be welcome.

Acknowledgment

The author is indebted to Mr. Lionel Andrews of Gutta Percha and Rubber (London), Ltd., who initiated the discussion leading to the preparation of these notes, and to colleagues in Monsanto Chemicals, Ltd., for helpful suggestions.

Welding of Thermoplastics

In this, the Concluding Section of Henning's Account of the Welding of Plastics (Translated from "Kunststoffe," April, 1942), Practical Application of the Technique is Discussed and the Possibility of Applying the Process to Other Thermoplastics Noted

ON the basis of the developmental work described in the first parts of this account ("Plastics," February, p. 53; and March, p. 97), and in the light of test results described, it is quite clear that the technical and industrial use of the welding process for polyvinyl chloride need entail no doubts as to its general efficacy, nor difficulties with respect to its practical application. Indeed, obstacles to be expected are, in general, of a less severe nature than those encountered in metal-welding practice, and complications such as were first met with when welding the stainless steels do not in any circumstances arise.

As in ordinary welding practice, the natural course of evolution has been to commence with comparatively small units, largely of an experimental nature and intended primarily for pilot plant; these being successful, the scope of the technique was extended, until, at the moment, as will be seen from the descriptions which follow, size of job constitutes no barrier.

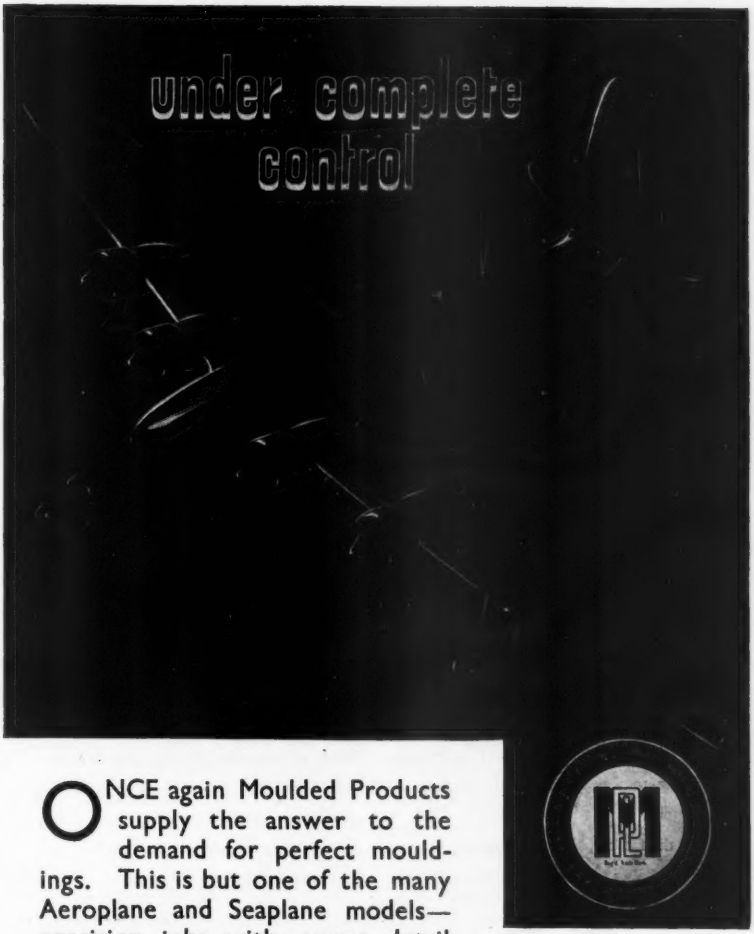
It will be observed that only few examples are quoted. These are, however, of a nature representative of the requirements of the heavy chemical industries. They are designed to show the broad avenues of use of welding, rather than to demonstrate in full all its possibilities.

No attempt has been made to indicate any modifications in design necessitated by a change over from metal to non-metal. Clearly, however, requirements, say, for a structure in stainless steel would differ markedly from those for one in polyvinyl chloride. This is indicated in the welding procedure adopted for fabricating the manifold referred to later in this account.

Strength requirements, too, call for some consideration. Indications of certain fundamental properties have been given in Tables 1 and 2, which appeared in previous parts of the account, and in Tables 3, 4 and 5, included here, will be found further valuable data (these last three tables, incidentally, should be read in conjunction with the text appearing in the second part of the account, "Plastics," March, 1943, p. 97).

Table 3.—Bursting Tests on Welded Hard Polyvinyl-chloride Tube (26 mm. i.d., 32 mm. o.d.)
Pressure increase about 1 atm. per sec.

	Type of weld	Bursting pressure, atm.	Time, secs.
Series 1	1	90	90
	2	85	90
	3	70	75
	4	90	93
	5	60	60
	6	110	120
	7	100	120
	1	110	106
	2	65	65
	3	55	60
Series 2	4	45	50
	5	55	55
	6	120	115
	7	100	90
	8	110	105
	—	110	120
	—	105	—
Series 3	4	55	—
	—	70	—

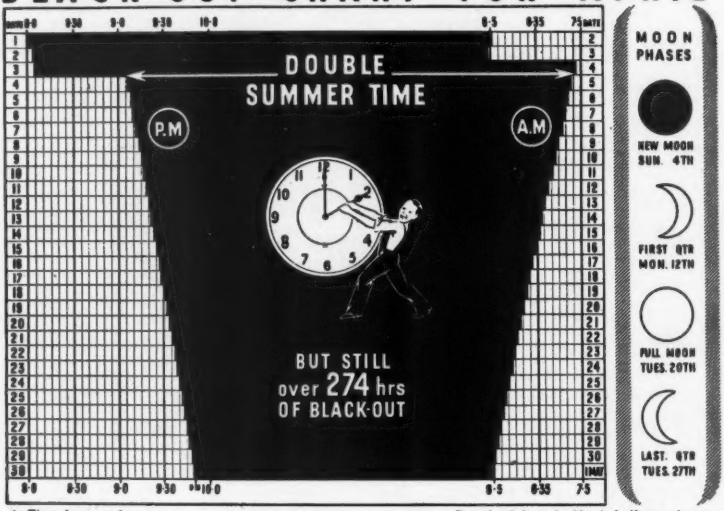


ONCE again Moulded Products supply the answer to the demand for perfect mouldings. This is but one of the many Aeroplane and Seaplane models—precision jobs with every detail in exact proportion—which we have produced from start to finish.

Moulded Products Ltd.
CHESTER ROAD, TYBURN, BIRMINGHAM

That Extra Hour . . .

BLACK-OUT CHART FOR APRIL



★ *Times shown are those for the London area.*

Reproduced from the Nautical Almanac by permission of the Controller of H.M. Stationery Office.

Again Double Summer time comes in April this year, which will be encouraging to the workers and beneficial to output.

In the factory, however, working twenty-four hours a day, there are still over 274 hours of black-out in April. Since no-one can see to work in the dark, good lighting is of the greatest importance, and it pays to see that it is supported always by dependable OSRAM Lamps.

Osram

A G.E.C. PRODUCT

THE WONDERFUL LAMP

Advt. of The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2

Bell Condenser Plates for Gas Washers

On account of the powerful corrosion which takes place in gas-washing plant, ordinary carbon steels can be applied in such structures only when it is possible to protect every part by a plastic coating. High nickel-chromium steels are resistant to this corrosive action, but in order to economize in the use of this alloy it was decided to make a welded polyvinyl-chloride assembly, as shown in

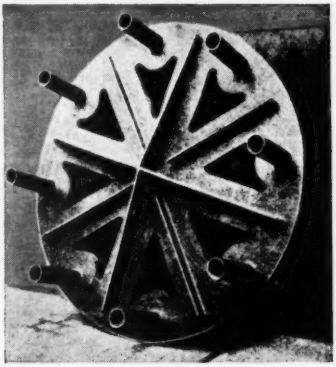


Fig. 11.—Illustrated above is view of underside of bell-condenser plate for gas-washing plant. This assembly, fabricated by welding from hard-grade polyvinyl-chloride sheet and tube, is some 6 ft. in dia. Shown at the right is view of the upper side of the plate with bells in position.

Fig. 11. The design shown was calculated to meet all service requirements.

The plates are 2,060 mm. in dia. and are placed one above the other in a tower, each plate being supported only at its periphery and being required to sustain a 60 mm. head of water. The construction of the bells themselves is shown in Figs. 12 and 13.

Jet and Distributor

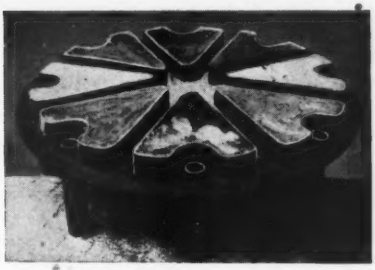
In Fig. 14 is shown a jet and distributor constructed by welding from polyvinyl tube and sheet; details of the assembly are shown in Fig. 15.

Fluid emerging from the jet in Fig. 14 strikes the cone and is distributed over a large area. All welds are carried out from both sides and are of the butt type; V welds are unsatisfactory in a case such as this on account of the high mechanical stresses which arise.

On account of marked chemical attack, the only alternatives to plastics for a component of this type would be glass or earthenware. Plastics, on the other hand, have the great advantage of being readily developed to shape and assembled by welding.

Manifold

Fig. 16 shows a manifold assembly produced by welding from polyvinyl-chloride tube. It has proved unsatisfactory merely to press the input tubes into the manifold and weld them into position, as cracks easily develop in the bigger tube as a result and the V welds joining the subsidiaries to the main pipe easily break away.



It is recommended that the subsidiary tubes be joined to the main tube with a firm butt joint, such a method of assembly having proved very satisfactory for this and other purposes, such as the production of T-pieces.

Condenser

In spite of low thermal conductivity of polyvinyl chloride, condensers in this plastic have frequently proved more satisfactory in resistance to powerful chemical attack than earthenware, glass, high-silicon iron and so on.

By means of welding, simple and perfectly satisfactory construction is possible,

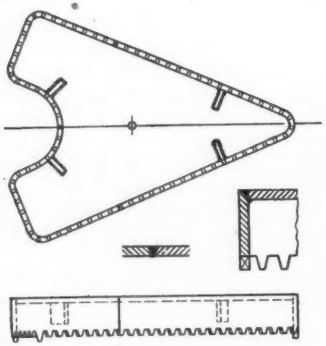
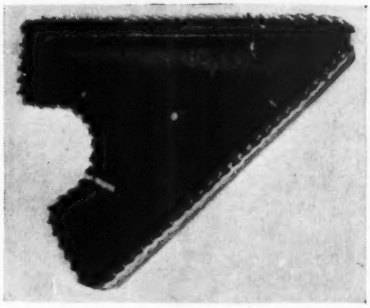


Fig. 12 (left).—Working drawing in outline of welded polyvinyl-chloride bell for condenser unit, shown in Fig. 11.

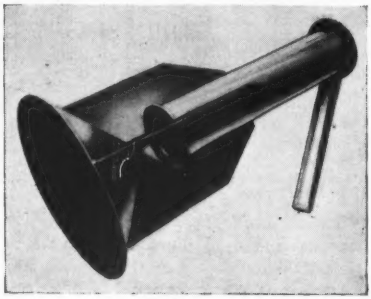
Fig. 13 (below).—View of underside of bell fabricated by welding as described.



whilst ease of replacement constitutes a factor of great importance. Condensers and coolers in the other materials mentioned, once damaged, can be repaired only with difficulty.

The condensers shown in Figs. 17, 18 and 19 have been tested for a period of two years. Water was used as a cooling medium and in most cases acted on the outside of the tubes, although, occasionally, water was passed through the tubes.

Among the purposes for which such coolers and condensers were used, were the cooling of gases (such as chlorine) and powerfully corrosive liquids, such as mixed-acid, and hydrochloric and sulphuric acids of various concentrations. In these last, impurities are frequently



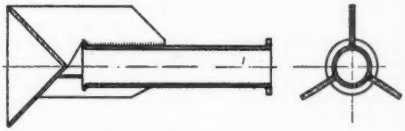


Fig. 14 (left).—Jet and distributor for chemical plant fabricated from polyvinyl chloride. Total length of unit shown is about 3 ft.

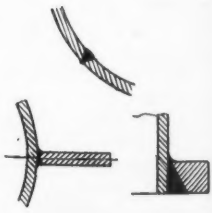


Fig. 16 (right).—Side and end views of manifold assembly in welded polyvinyl chloride. Here the subsidiary tubes are welded to the main tubes by butt welds in order to guard against breaking-away, under lateral stress, of the former.

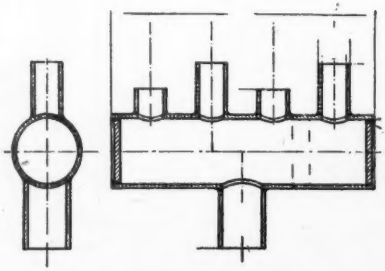


Fig. 15 (above).—Working drawings in outline, showing assembly details for the jet and distributor illustrated in Fig. 14. All joints are by V welding, as loading when in operation is relatively severe.

Table 4.—Bending Tests with Hard Polyvinyl-chloride Tube (26 mm. bore, 32 mm. o.d.; 28 mm. bore, 22 mm. o.d.). No Internal Pressure.

Type of Weld	Breaking load kg.	Deflection mm.*	Remarks
1	300	95	Unbroken†
2	295	35	Broken
3	127	8	Broken
4	200	15	Broken
5	320	33	Broken
6	317	95	Unbroken†
7	227	18	Broken
8	310	38	Unbroken†
1	320	30	Broken
2	217	18	Broken
3	328	33	Unbroken†
4	270	23	Broken
5	317	28	Broken
6	260	20	Broken
7	177	15	Broken
8	330	40	Unbroken†

* See Fig. 6, p. 57, "Plastics," Feb., 1943. Deflection is measured at centre point between two points of application of load equidistant on each side of weld; tube itself being placed for bending on two supports, as shown in Fig. 6 loc. cit.

† Where breaking did not take place the polyvinyl chloride lost its transparency in the neighbourhood of the points of support and load, and on the tension side of the bend; cracking then took place.

present which enhance their corrosive powers.

From both the chemical and mechanical standpoints, welding has proved the best means of assembling such units.

Plates for Suction Filter Press

Filter plates may be constructed by welding from polyvinyl-chloride tube and

Table 5.—Bending Tests with Hard Polyvinyl-chloride Tube (26 mm. bore, 32 mm. o.d.). With Internal Water Pressure 2.5 atms.

Type of weld	Breaking load, kg.	Deflection, mm.*	Remarks
1	255	15.5	Broken
2	150	9.0	Broken
3	130	7.0	Broken
4	180	10.5	Broken
5	150	7.0	Broken
6	270	15.0	Broken
7	240	17.0	Broken
8	360	30.0	Unbroken†

* See Fig. 6, p. 57, "Plastics," Feb., 1943. Deflection is measured at centre point between two points of application of load equidistant on each side of weld; tube itself being placed for bending on two supports, as shown in Fig. 6 loc. cit.

† Where breaking did not take place the polyvinyl chloride lost its transparency in the neighbourhood of the points of support and load, and on the tension side of the bend; cracking then took place.

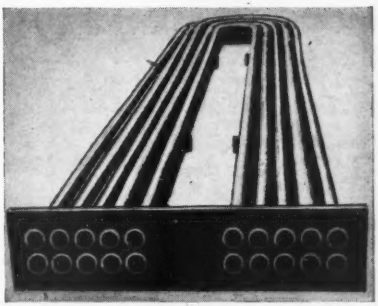


Fig. 17.—Large pipe condenser built up from polyvinyl-chloride tubes, the open ends of which are welded into the end plates as shown. This condenser, and those illustrated in Figs. 18 and 19, has been in use for some years with every satisfaction, being employed for cooling, among other things, gaseous chlorine.

sheet, as shown in Fig. 20. The filter plate in use is covered with special polyvinyl-chloride filter cloth through which filtrates are drawn by means of a vacuum. Precipitates remain behind on the cloth from which they are afterwards scraped by means of a knife edge.

If the liquid being filtered be excessively hot, or if too high a vacuum be employed, the frame may be distorted by

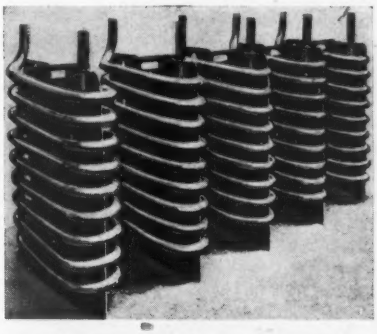


Fig. 18.—Bank of cooling coils fabricated in polyvinyl-chloride tube and assembled by welding. Here, as in the case of the plant previously described, size constitutes no limitation for the adoption of the welding technique. (See, for example, "Plastics," Nov., 1942, p. 382, Fig. 23.)

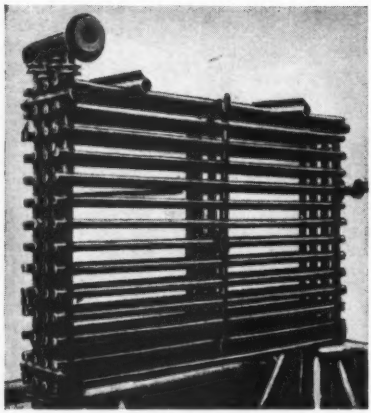
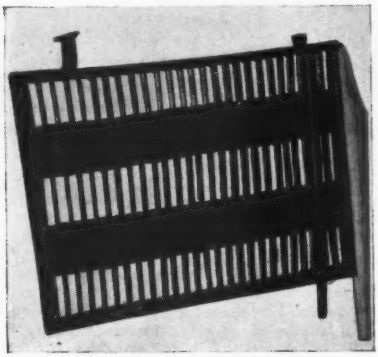


Fig. 19.—Battery of cooling tubes assembled into end plates by welding. It will be observed that this design makes use of straight cut-off lengths, no bending being required. Note valve at upper left-hand corner of the battery. For full account of polyvinyl-chloride valves for plant of this and other types, see "Plastics," Oct. and Nov., 1942, pp. 340 and 380 respectively.

the weight of the precipitate, but it has been demonstrated that the welds in such a frame are not destroyed under these conditions (see, for example, Fig. 21). If the frame so-distorted be heated to about 130 degrees C. it may be restored to its original form without difficulty. No danger need be apprehended as the welds deform equally with the parent material.



Summary

The researches recorded have shown that the new welding process may be employed with the utmost safety for the assembly of structural components in polyvinyl chloride. Factors of safety in general should be the same as those laid down for gas or arc welding in steel.

Against chemical attack, welds in polyvinyl chloride are as equally resistant as the parent plastic. The welding system described may be used not only for hard grades of polyvinyl chloride but also for the softer grades containing plasticizer and filler. When welding softer grades, filler rod should be chosen of a composition the same as that of the plastic. When hard polyvinyl chloride is to be welded to softer grades of the same plastic, unplasticized filler rod should be used.

Whether or not all thermoplastics may be welded in the manner described, and with equal success, still remains to be demonstrated. Nevertheless, apart from the polyvinyl-chloride plastics, mixed polymers, such as Astralon and Decelith, may be so joined, as also may be polymethyl-methacrylate resins, etc.

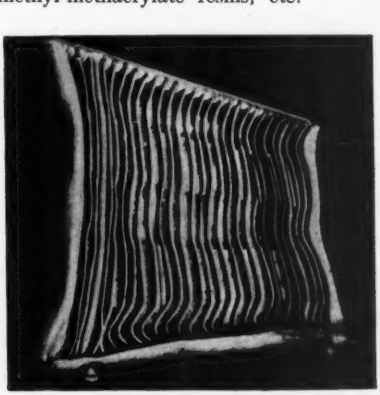
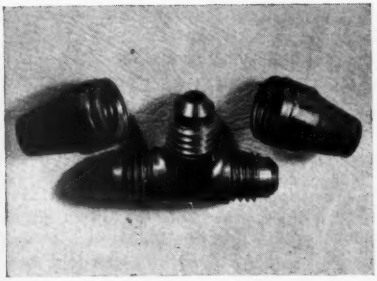
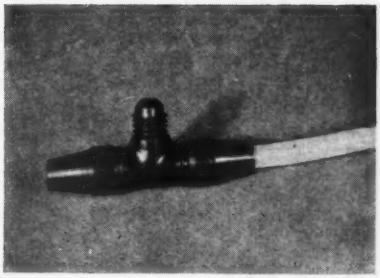


Fig. 20 (left).—Plate for filter press fabricated in hard-grade polyvinyl chloride. This is used in conjunction with polyvinyl-chloride filter cloth. Fig. 21 (above).—Plate, as shown in Fig. 20, distorted by excessive heat and vacuum loading. Welds have not given way and the plate was subsequently restored to shape by warming to 130 deg. C. and flattening.





Injection moulded jointings for Saran tubing.

SARAN TUBING

WE have already given some publicity (see "Plastics," December, 1942, p. 429) to the very valuable properties of Saran the polyvinylidene chloride extrusions in tubular and strip form made by Dow Chemical Company; the qualities of high mechanical strength and chemical resistance make the material a new tool for engineers, chemists and manufacturers in general.

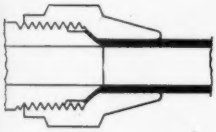
The tubular form is now being widely employed in the U.S.A., not only in laboratories but also in so-called home construction, and it is interesting to note in this connection how readily flaring and jointing can be carried out.

We have recently received from R. W. Greeff and Co., Ltd. (the agents in Great Britain), samples of L and T joints injection-moulded from polyvinylidene chloride, and a note containing simple instructions for carrying out the jointing of the tube.

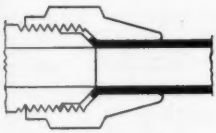
The flaring of Saran tubing is done by

using standard equipment as shown in the accompanying photographs and diagrams. The operation should be carried out at room temperature or above, and if below 50 degrees F. the tube and flaring tool should be warmed.

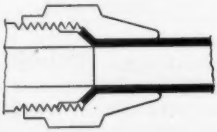
The end of the tube is inserted in the appropriate hole in the tool and cut flush with the upper surface of the clamp. On applying the clamp pressure, care must be taken to ensure that the tube does not slip through the clamp, producing too short a flare, or that the tool is not forced into the tube so hard that the flare is made thin and weak.



Incorrectly flared tube. Too thin and weak.



Incorrectly flared tube. Too short —joint likely to pull out.



Correctly flared tube. Proper length and thickness.

World's Industry Employs Plastics

SHIPBUILDING

Lightweight plywood for boat hulls built up according to a technique of multi-directional pressures are considered by Barnes in "Mechanical Engineering," 1943/65/14. The Vidal process, using flexible rubber bags, is employed to obtain such pressures. Actual bonding is by means of plastic adhesive. The author emphasizes the need for an intimate knowledge of wood technology, and for accurate calculation of pressure requirements if fully satisfactory results are to be obtained. He indicates that the publicizing of this method may have been somewhat premature and is certainly misleading; further research and development are necessary. The account concludes with an extensive bibliography.

AIRCRAFT

Theory and practice of plywood for aircraft are discussed by Allward in "Mechanical Engineering," 1943/65/14. The author summarizes the properties required in plywood for this purpose and discusses the shortcomings of natural glues, and shows how thermoplastic resins and thermosetting resins have replaced them and the advantages which have been derived. Particular attention is paid to the urea-formaldehyde glues. Utilization of plywood as a structural material generally, strength of cylindrical bodies and weathering properties of plywood are also dealt with.

GENERAL ENGINEERING

Stress distribution in double-ended eye bar in tension was recently investigated by MacGregor, of the Mass. Institute of Technology ("Mechnical World," 1943/113/193). Photo-elastic methods were used and the development of particularly high stresses at the inside of the hole and at the beginning of the upset in the bar were observed. MacGregor also studied stress distribution in a phenolic resin unit featuring a hole and subjected to vertical loading. Stress concentrations at the fixed end of a cantilever were also examined. **Interrelation between lattice structure and mechanical properties** of moulded phenolics is discussed by Siegfried in "Schweizer Archiv f. angew Wissenschaft," August, 1942. **Substitute materials** were considered in detail by Vieweg in a lecture reported in "Schweizer Archiv. f. angew. Wissenschaft," 1942/8/291. A very clear indication is given of current trends in German science and industry and of the attention being given these in Switzerland.

TEXTILES

Raincoats, hospital sheeting, life-preserving jackets and other equipment for the U.S.A. Army are now being made from fabric treated with vinyl-acetal in place of rubber. Known as the Saflex coating process, the technique required has been developed by J. L.

Haas, Technical Director, The Hodgman Rubber Co. **Waterproof fabric wrapping** for intricate munition and machine parts, and designed to replace the use of grease coatings, has been developed in U.S.A. It consists of a cellulose base impregnated with suitable waterproof materials. **Spinneret fittings for rayon and cellulose wool** are considered by Holzmann in "De Gussa Metallberichte" (Abstract, V.D.I. Zeitschrift, 1942/86/579). With the object of saving precious metals various non-metallic substances were tried out, including ebonite, the chemical resistance of which was found satisfactory. Most favourable results were obtained with stainless steel. Nevertheless, polystyrene and luvican also proved suitable for certain parts of the spinneret assembly.

ELECTRICAL

Special wiping dies and holders for such dies are required for coating wire with high viscosity insulators, such as Nylon and Formvar, which are now being employed on coil windings. Emig ("Wire and Wire Products," 1942/12/716), refers to developments in this connection made in the wire enamel laboratories of Du Pont de Nemours. Cone-shape dies, self-aligning die holders, and suggestions for heat distribution in the oven are discussed.

MISCELLANEOUS

Earplugs moulded in smooth, translucent plastic have been developed by the Maico Co., of U.S.A. Plugs are reproduced from a special impression taken of each ear. They are said to fit the channel comfortably and cannot fall out under the most arduous conditions. **Bayonet scabbard in Tenite** (cellulose acetate/butyrate) is being supplied to U.S.A. troops. Compared with the ordinary type constructed of wood and leather, it is exceedingly light. **Plastic contact lenses** and method of attaching them to the eyeball are described in the December, 1942, issue of "Scientific American." **Lacquering of phosphate-treated black plate** formed the subject of investigation by Schuster, reported in "Stahl und Eisen," 1942, p. 685. The lacquers employed were of the phenolic and cresole types. **Substructure of metallic surfaces** was studied by means of the electron microscope by Heidenreich and Pech, "Journ. Appl. Phys.," 1943/14/23. Surface is duplicated on polystyrene, from which a "print" is taken by evaporation of a silica film. **Fused salt-bath treatment of wood** is referred to in "Machine Design," Jan., 1943. The system, designed permanently to inhibit shrinkage in wood, consists in passing the dry material continuously below the surface of a fused bath of sodium and potassium acetates at 290 degrees C. **Pine resin and vegetable fibre** form the basis of a new plastic composition referred to in "Scientific American," for Feb., 1943, p. 61. It is of low s.g. but sturdy, and may be used as an efficient substitute for sheet metal for such structures as air ducts, corrugated sheet containers, etc. The resin-treated fibre is turned out in sheets on standard paper-making machinery. The sheets are subsequently hydraulically pressed. **Wooden skis** of high hardness and wear resistance and stabilized against warping due to long exposure to damp, are being manufactured in U.S.A. on a mass-production basis by the Vidal process. It is said that these skis need not be kept in clamps in order to retain their shape when not in use. **Comprehensive summary of the chemistry of phenolic resins** is presented by Euler in "Angew. Chem.," Vol. 54, pp. 458-461. Of particular interest are Euler's remarks concerning the biochemical reactivity of certain unstable intermediate products of the condensation.

Plastic Film and Sheet for Small Coil Insulation (Contd.)

The Author Continues His Critical Examination of the Part Modern Plastics Play in this Important Branch of Electrical Insulation

by E. E. HALLS

IN the March issue were given the methods of test and results of these tests of a large number of films which have been considered possible for small coil insulation.

The following are broad comments upon the test results:—

(a) Influence of Moisture

Under the water immersion tests, polythene shows a swelling in thickness, but negligible change in length and width dimensions or in weight.

Of the Continental cellulose acetates, one showed expansion in all dimensions and two marked shrinkage. Marked loss in weight occurred but negligible fluctuation in bursting strength.

The dimensional movement in the British cellulose acetate of electrical quality is largely expansion, degree quite marked; bursting strength remains reasonably constant. The flexible acetates show appreciable shrinkage but constant strength.

Of the polyvinyl chlorides, all show large movement; the first shows shrinkage in length and breadth and expansion in thickness, while in the other three the reverse movement occurs. The first shows a large weight loss, and the other three a gain. The tendency on bursting strength test is to become elastic.

(b) Influence of Dry Heat

Extended periods at 60 degrees C. cause shrinkage in length on all samples, very marked on polyvinyl chloride and next severe on the polythene samples. The flexible cellulose acetates are the worst of that group.

In the width dimension the polythenes show a marked expansion; all other materials a marked shrinkage. This is very severe on the polyvinyl chlorides and the flexible acetates.

In the thickness direction, behaviour is very mixed with both expansion and contraction. Polyvinyl chloride shows maximum deviation in both directions, polythene in expansion. Acetates lie intermediately with marked movement, some samples in one direction, some in the opposite.

Loss in weight is heaviest in polyvinyl chloride, lightest in polythene. Virtually no deterioration occurs in bursting strength.

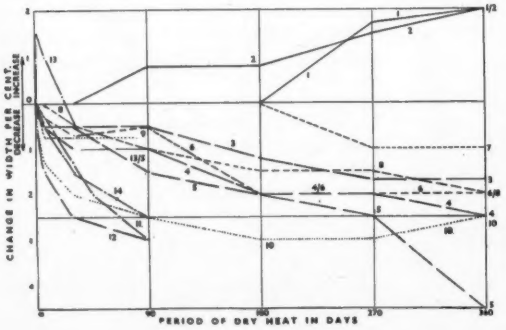


Fig. 8.—Effect of dry heat at 60°C. upon width of plastic films.

Fig. 10 (right).—Effect of dry heat at 60°C. Loss in weight.

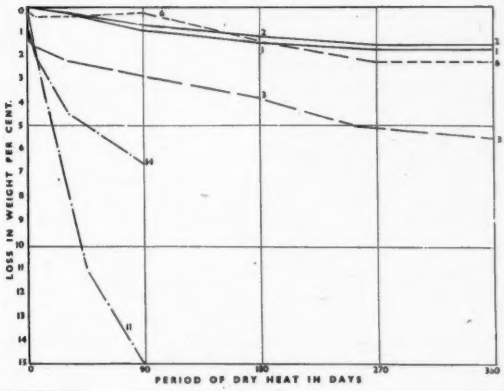
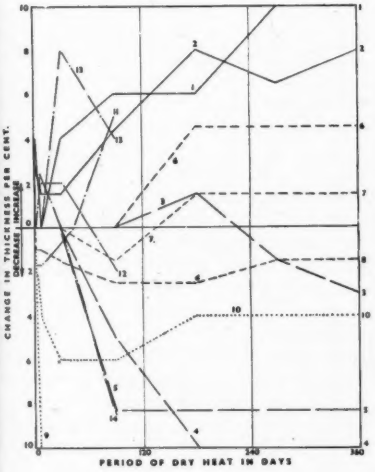


Fig. 9 (below).—Effect of dry heat at 60°C. on thickness of plastic films.



(c) Effect of Moisture and Warmth

Polythene samples are really very little affected, but all others show heavy shrinkages in length and breadth, and fluctuating results in thickness. The polyvinyl chlorides and flexible acetates are among the worst of the specimens. Similar remarks apply to weight changes, polythene being very good, polyvinyl chloride very poor. Bursting strength remains reasonably level.

Experience with polythene in the form of thicker sheets and in the form of heavy sleevings or cable coverings suggest that this material should be very stable under all the test conditions imposed. Some of the results with the polythene films, therefore, are a little disappointing and

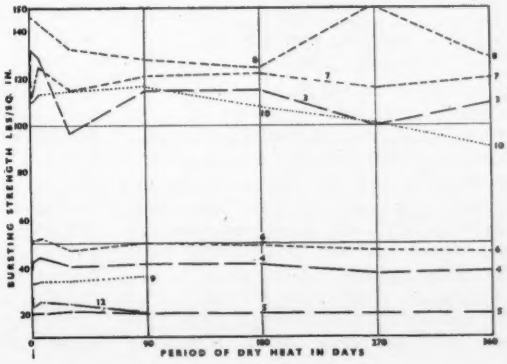


Fig. 11.—Effect of dry heat at 60°C. on bursting strength of films.

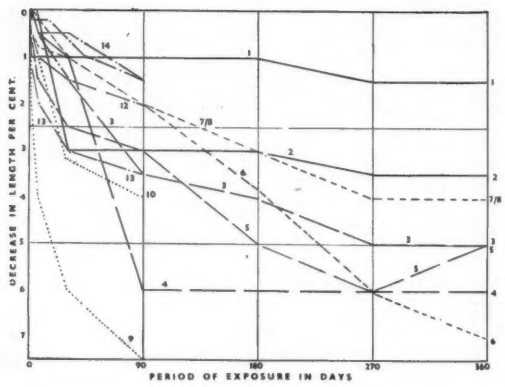
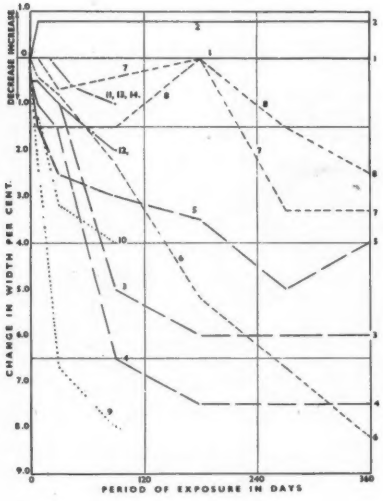
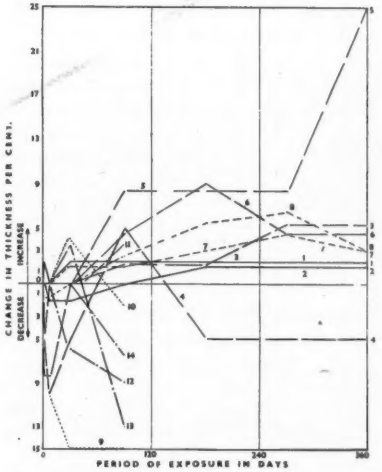


Fig. 12 (left). — Effect of fluctuating warmth and moisture on length of films.

Fig. 13 (below, left).—Effect of fluctuating warmth and moisture on width of films.

Fig. 14 (below, right).—Effect of fluctuating warmth and moisture on thickness.





suggest that some further advance in this direction is necessary.

With regard to the cellulose acetates, it will be noticed that the flexible plasticized grade and the ordinary packing-material type are not sufficiently stable dimensionally, and, moreover, that the other grades behave in a manner characteristic of the source from which obtained.

The polyvinyl chloride materials likewise are not so stable as considered required for coil manufacture. Apart from dimensional stability, one of the drawbacks of cellulose acetate is its stiffness, and both polythene and polyvinyl chloride can be produced in grades having that degree of limpness that is desirable. Again, polythene is particularly attractive because it is an all hydrocarbon material, whereas the polyvinyl chloride is an unsaturated compound containing chlorine. However, as earlier stated, no instances have been recorded

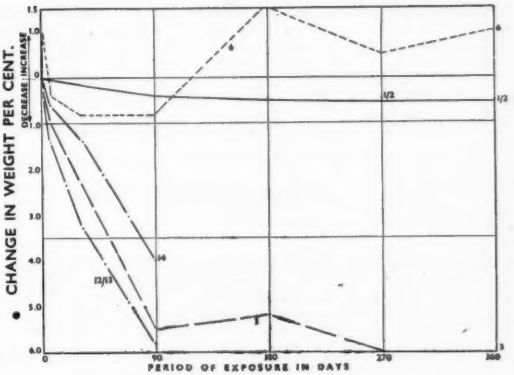


Fig. 15.—Effect of fluctuating warmth and moisture on weight of plastic film materials.

in which material put forward for electrical purposes has shown any evidence of this combined chlorine becoming freed and appearing as ionizable chlorides to any notable degree.

Table 4 gives the total chlorine values of the materials tested, and it also gives the free ionizable chlorine content both before and after exposure to the fluctuating temperature and humidity conditions. It will be noted that under these conditions the material did not deteriorate in this respect.

Table 5 summarizes in a self-explanatory manner the behaviour of cellulose acetate samples Nos. 2 to 8 inclusive under the ageing tests, strip specimens being fixed to 36 per cent. nickel steel ("invar") base plates. The latter were 8 ins. long, 2½ ins. wide, 3-32 in. thick. The cellulose acetate test pieces were 1 in. wide and 6 ins. long. They were fixed at their ends by means of a cement consisting of 10 per cent. virgin nitro cellulose scrap in acetone. Fig. 19 shows the arrangement of the test piece in taut and slack conditions.

Space does not permit of detailed discussion of the properties of natural insulating materials and their fluctuations under ageing conditions. Nevertheless, to give some information upon this, the effects of dry heat at 60 degrees C. and of water immersion are given in Tables 6 and 7 and Figs. 16 and 17 for a number of varnished fabric materials. The latter comprised:—

Sample A.—A tropical quality of yellow varnished cambric, thickness 0.005 in., source A.

Sample B.—An ordinary quality of yellow varnished cambric, thickness 0.005 in., source A.

Sample C.—An adhesive quality of yellow varnished cambric, thickness 0.005 in., source A.

Sample D.—An ordinary quality of yellow varnished cambric, thickness 0.005 in., source B.

Sample E.—A black bituminized varnished cambric, thickness 0.006 in., scource B.

Sample F.—An ordinary

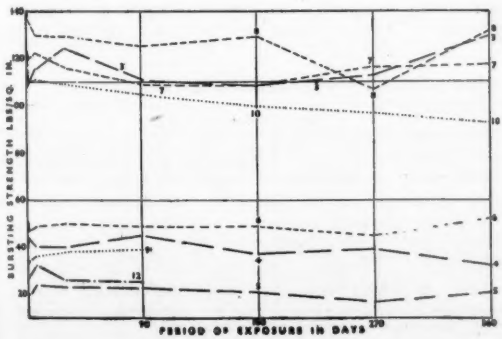


Fig. 16.—Effect of fluctuating warmth and moisture on bursting strength.

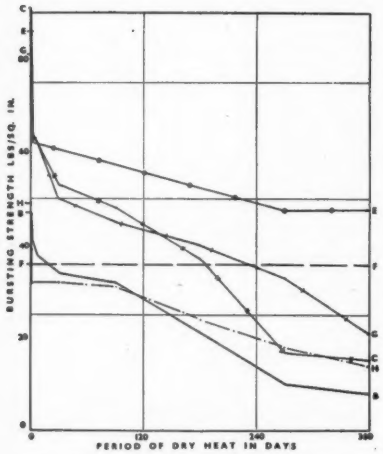


Fig. 17.—Change in bursting strength of varnished cambric at 60° C.

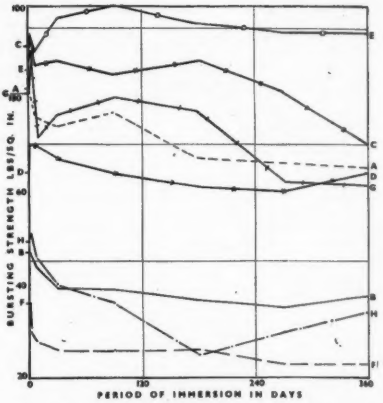


Fig. 18.—Change in bursting strength of varnished cambric under water immersion.

yellow varnished silk, thickness 0.003 in., source C.

Sample G.—An ordinary yellow varnished cambric, thickness 0.005 in., source C.

Sample H.—An ordinary yellow varnished cambric, thickness 0.005 in., source D.

The data presented concern bursting strength and are self-explanatory, and the only comment required is the fact that heat is detrimental to all the materials—seriously detrimental, except with the varnished silk.

One characteristic of polythene, viz., softening point, should be noted because it may be a shortcoming in some cases. This material melts rather sharply in comparison with other synthetic resinous plastics. The temperature of change from definite solid to viscous liquid lies between 100 and 115 degrees C., whereas that of cellulose acetate is gradual and indefinite, generally between 115 and 170 degrees C. With the pressure imposed by the heavy tension of closely wound windings, operating temperatures cannot be permitted to approach the melting point of the plastic. Operating temperatures are, of course, the additive effects of ambient temperature and heat engendered in the coil under the wattage load at which it operates. However, for various reasons, 75 degrees C. is regarded as the maximum safe service temperature for most coils of this class,

Table 4.—Chlorine Values of Polyvinyl Chloride Film Specimens.

Sample No.	Total chlorine content per cent.	"Free chlorine," per cent.	
		Initial	After 30 days' exposure to fluctuating temperature and humidity conditions
11	36.6	Minute traces	Minute traces
12	34.8	0.035	0.022
13	32.6	0.068	0.045
14	35.3	0.020	0.014

Note.—"Free chlorine" signifies water soluble ionizable chlorides.

Table 5.—Behaviour of Strips of Cellulose-acetate Film fixed to 36 per cent. Nickel-steel Base Plate under Accelerated Condition Tests.

Test	Conditions	Behaviour of film
1	Water immersion	Very slack in 6 hours, no apparent change in 7 days. Upon exposure to atmospheric conditions in laboratory, gradually shrunk and became taut
2	Dry heat at 60°C.	Very taut in 6 hours, no apparent change in 7 days
3	Fluctuating temperature and humidity conditions	Very slack in 6 hours, no apparent change in 7 days. Became taut upon re-exposure to laboratory atmosphere

Table 6.—Results of Prolonged Exposure Tests on Varnished Cambrics. Effect of Dry Heat of 60°C. upon Bursting Strength.

Sample No.	Bursting strength, lb./sq. in., after period of:—							
	Initial	1 day	1 week	1 month	3 months	6 months	9 months	12 months
B	47	41	38	34	32	21	10	8
C	91	54	66	53	48	37	17	15
E	86	62	64	63	61	61	47	49
F	36	36	36	39	37	37	35	34
G	81	63	62	50	45	40	33	21
H	49	32	34	32	31	24	18	14

Table 7.—Results of Prolonged Exposure Tests on Varnished Cambrics. Effect of Immersion in Water upon Bursting Strength.

Sample No.	Bursting strength, lb./sq. in., after period of:—							
	Initial	1 day	1 week	1 month	3 months	6 months	9 months	12 months
A	82	83	76	74	77	67	—	65
B	47	47	44	39	39	37	35	38
C	91	94	87	88	85	88	81	70
D	64	70	70	67	64	61	60	64
E	86	94	90	97	102	96	94	94
F	36	30	28	26	26	26	23	23
G	81	90	71	76	80	77	62	61
H	49	51	46	40	36	25	30	34

and polythene should withstand this safely.

One of the major features claimed for the plastic films in this application is that they are pure chemicals or mixtures of chemicals, with no retained processing chemicals such as inorganic acids, alkalis or salts. In this they differ markedly from the natural group of treated papers and textiles. For this advantageous factor to be exploited to the full, the plastic materials must be cleanly handled during the fabrication operations in the course of their conversion to coil components. This emphasizes that coil washers must be blanked dry on clean machines, with clean tools, and collected in clean containers. It relegates the job to the machine benches of the actual coil-winding shop, and its control to those fully accustomed to, and acquainted with, problems of coil hand-

Table 8.—Some Electrical Characteristics of Plastic Film Materials.

	Cellulose acetate	Polythene	Polyvinyl chloride
Electric strength, volts A.C., 50 cycles, in air at 20°C.	2,000/2,500 volts/mil.	1,000/1,500 volts/mil.	500 volts/mil.
Dielectric constant at 50 cycles, 20°C. ..	4.9	2.2	3.2
Surface resistivity at 20°C., 75% humidity, ohms/cm. sq.	6×10^{12}	1×10^{14}	1×10^{12}
Volume resistivity at 20°C., 75% humidity, ohms/cm. cube	6×10^{14}	1×10^{17}	1×10^{14}
Power factor at 50 cycles	0.023	0.0006	0.04

ling. It prohibits the job being carried out in the regular machine shops where press lubricants, soap emulsions, tallows, etc., are invariably encountered, where it is impossible to work dirt-free, and where, in general, one finds little appreciation of the value of material or the need for avoidance of damage to it.

Regarding coil-assembly problems, of which there are a number that bear

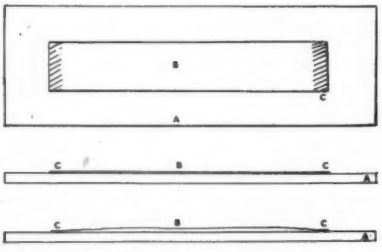


Fig. 19.—Arrangement of fixed strip test piece: A, nickel-steel base plate; B, plastic film specimen; CC, cemented ends; the specimens below show taut and slack conditions.

directly upon the material question, some observations from a particular practice, which is a fairly common one, should prove helpful. These are given in the following paragraphs.

The width of insulation for covering coil and windings is that which serves this purpose and avoids any possibility of end-turns slipping around the insulation to contact the core. Unfortunately, the length of the winding space for any given type of spool assembly is not a constant, but embodies the sum of a number of manufacturing tolerances. The latter will at least include the tolerances on width of knurls, position of knurls in relation to one end of the core, and thickness of cheeks, with the cheeks finally assembled to a dimension over the cheeks and not within them. For example, in the case of the solid core shown in Fig. 21, the important dimension from the electro-magnetic angle is the length AB. The knurls at C and D are to take solid Bakelite laminated cheeks, of which the one at C would be assembled and forced against the solid core end, and that at C would be pressed in position located from D. The length of winding space, that is, distance between cheeks, is a summation of plus and minus errors on length of core, thickness of its solid end, thickness of cheeks, and accuracy of their

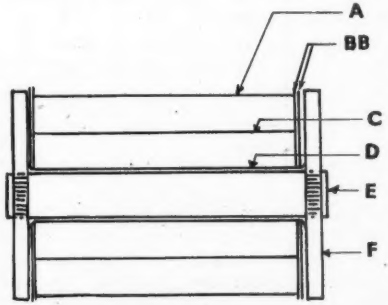


Fig. 20.—Insulation of small coil: A, outer cover; BB, two cheek washers; C, interleaving between two windings; D, core cover; E, metal core with knurls to hold cheek; F, cheek.

assembly. There are practical advantages in this modus operandi and no objections providing that the winding space is large enough to house the winding, and that the insulation can cater for all variations. Using varnished cambrics and treated papers, no difficulty arises from a $\frac{1}{16}$-in. variation. The insulation is cut with a plus tolerance to allow for this, plus a further margin to allow slight

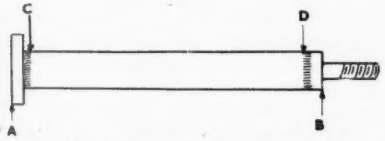


Fig. 21.—Typical core showing important dimensions and knurls.

turn-up at the cheeks, as shown in Fig. 20. With polythene, the same practice can be followed, but cellulose acetate is not sufficiently flexible to withstand the strain at the turn-up, and it tears. In both cases, in view of the nature and expense of the material, it is desirable to use a " constant " width material purchased in rolls or pads, and which have been cut to commercial tolerance on width. The difficulty is overcome by using formed cheek washers, split when necessary for assembly. The type is shown in Fig. 22. Using this construction, the core is covered with insulating material, unavoidably leaving a possible gap between insulation and cheeks, but arranging limits and assembly methods so that this gap lies within the limits 0.000 to 0.031 in. maximum, or, at the worst, 0.062 in. maximum. The thickness of washer and height of form at the central hole can then take care of this. It is preferable, in addition, to redesign assembly operations to fit the spool cheeks to an inside dimension, instead of to one external to them. Another feature not bothered with flexible insulation, although always a potential source of trouble, concerns the knurls. These should not extend into the winding space, but should be completely covered by the cheeks, or any plus tolerance required should be arranged for beyond the cheeks and not within them.

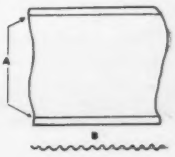
In one particular assembly technique using cellulose acetate, the core covering material is 0.002 in. thick, and two turns with the appropriate overlap are applied. It is anchored to the core and cemented to itself with a nitro cellulose adhesive having an acetone carrier. The formed cheek washers are assembled, cemented to the cheeks with the same adhesive, which is also used to seal the junction between washers and core cover. The necessary number of loose washers are added of flat, not formed, construction, in accordance with the number of outgoing leads for which provision has to be made, that is, one flat washer per lead.

It will be noted that in this construction the " lining " of the spool is completely of insulation of non-fibrous type and with all junctions sealed. Consequently, if condensation occurs, no moisture can be trapped to cause dangerous paths of electrical leakage to core.

With regard to inter-leavings between windings, these would use 0.002-in. material, again with two layers and the appropriate overlap, and with the latter cemented. With fine wire windings, trouble is experienced when the winding space is on the maximum dimension and the interleaving material on the minimum, from the wire slipping off the end of the insulation into the lower winding. One method used and claimed to overcome this difficulty employs an interleaving corrugated at its end for a depth of about $\frac{1}{8}$ in., as shown in Fig. 23. A

Fig. 22 (left).—Cheek washer with formed centre.

Fig. 23 (right).—Interleaving plastic with corrugated edges. Depth of corrugation at A and height at B.



corrugation of this nature is readily applied to cellulose acetate by passing between heated wheels at a temperature best determined by trial, within the range 80 to 150 degrees C. This same type of interleaving suits the first outer cover, that is, the one next to the winding itself, using two turns plus the overlap. Coils that are to receive much handling in assembly, store, inspection, etc., need, additionally, a robust outer cover for mechanical protection. A further covering of the same material can be used, but a good procedure is to employ a flexible grade of cellulose acetate, thickness 0.004 to 0.005 in., using one or two layers plus the sealing lap according to the size of coil.

Joints made by soldering, either at breaks in the winding wire, or where lead-out wires are joined, are insulated by covering with a fold of 0.002-in. cellulose acetate film. The solderings must be smooth, as any sharp points would cut through the acetate.

Using polythene film insulation, very much the same technique can be followed.

These techniques are being developed in order to produce sound, dry coils, not moisture-proof coils. In the latter, impregnation is essential and so many difficulties are encountered in its application in practice, and the impregnated coils so produced still give failures from impurities or faults in them. The possibilities of clean, dry windings, with plastics ensuring insulation and purity values, design ensuring freedom from textiles and material leakage paths, and production technique taking care of cleanliness, and again leakage paths, or other faults, have been established as an advance in the art of small coil manufacture and are beyond the experimental stage. Much remains to be done on the plastics side, with a view to improving cellulose acetate and hastening the availability of polythene in suitable grades.

Finally, as a guide for designers, some electrical values are given for cellulose acetate film, polythene and polyvinyl chloride in Table 8. It is always desirable to check actual constants with which one is concerned upon particular grades of material contemplated, but the values given present an average picture.

Spraying of Plastics

The application of synthetic resins in the manufacture of anti-corrosive and anti-fouling paints and films, has, of course, been practised since this type of resin first entered the paint world. Invariably they are mixed with special inhibitors or anti-corrosion compounds, or chemical substances, such as mercury, copper and zinc salts, which deterred the attachment of marine growths to ships' bottoms. Such paints are applied by the very simple process of brushing.

A new type of anti-fouling treatment has been announced by Plastic Sprays, Ltd., with the development of the Plastoglaze process. It would appear to be specially applicable to the treatment of the smaller type of boat, since the process entails spraying machinery.

The Plastoglaze process permits the rapid application and cure of coatings based on phenol-formaldehyde resins without the use of stoving ovens or other complicated or bulky apparatus. The advantages of such a process will be apparent to those acquainted with the use of resin-base finishes which, in the past, have been of either the cold-setting or of the stoving type.

The coating composition used in the Plastoglaze process is a carefully balanced combination of a phenol-formaldehyde resin, plasticizer, accelerator and thinners. The coating is sprayed on to the surface, and within a few minutes of spraying a special heat treatment is applied which enables the coating to be cured completely in 10 minutes.

Metals may be similarly treated, but here good results are also obtained by first spraying the surface with zinc powder. This preliminary treatment gives a thin, rough and slightly porous layer which results in good adhesion of the resin finish. At least two coats of the finish are needed for metals which have received a coating of zinc; the first resin coating sinks into the pores of the zinc resulting in a matt finish of high abrasion resistance. The second coat provides a high gloss and further protection for the metal and zinc coating.

EMPIRE
TRADE MARK
VARNISHED
INSULATING
MATERIALS
Seamless Tape
THE MICANITE
& INSULATORS
COMPANY LIMITED
MIC
WALTHAMSTOW
LONDON. E.17.

BELL TELEPHONE LABORATORIES USE THIS

12-oz. H-P-M PLASTIC INJECTION MOULDING PRESS

TO OBTAIN ACTUAL PRODUCTION DATA FOR THEIR NEW THERMOPLASTIC TELEPHONE PARTS

Shortage of metal has demanded intensive development work on thermoplastics as substitute materials for telephone parts, including such complicated forms as the combined set housing. To carry on this experimental programme the more effectively, Bell Telephone Laboratories have recently installed an H-P-M injection moulding press.

Perhaps your products can be moulded. May we help you to plan your production?

Enquiries to SOLE AGENTS AND ENGINEERING REPRESENTATIVES

A.C. Wickman LIMITED

COVENTRY • ENGLAND

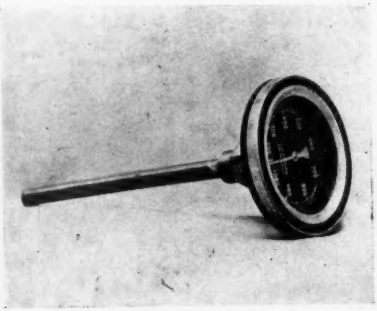
LONDON BRISTOL BIRMINGHAM MANCHESTER LEEDS GLASGOW NEWCASTLE

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

HEAVY DIAL THERMOMETERS.—For industrial application the glass and mercury thermometer has the obvious disadvantages of being easily broken, difficult to read, and often inconvenient to use. In these difficult times as regards replacement, breakage is itself a serious matter.

Accordingly much interest attaches to the "Heavy Industrial" motor dial thermometers made by the British Rototherm Co., Ltd., of London (Merton Abbey, S.W.19), available in three types, that is the co-axial, vertical, and flange. Like the other multi-helical bi-metal strip thermometers made by the firm for many



different applications and conditions, these have a metal stem and a metal dial with heavy plate-glass front and chromium-plated bezel, like a small clock or pressure gauge, with the pointer moving over a graduated temperature scale which can be read easily from a considerable distance. Each of these models also has three standard sizes of dial, 2½-in., 4-in. and 7-in. diameter, with also two standard stem diameters, $\frac{5}{8}$-in. and $\frac{5}{16}$-in., the stem being made of a length to suit the application.

The co-axial design has the dial at right angles to the stem, that is like a clock face with the stem at the back, while in the vertical design the dial is parallel with the stem, that is like a clock face with a stem in the place usually occupied by the pendulum. Also the flange model with co-axial dial is particularly suitable for ovens, a gland being provided for double-walled ovens, tanks, or other equipment, the gland making a secondary joint with the inner wall and a main joint with the outer wall.

It may be mentioned also the co-axial model has the advantage that the small bi-metal multi-helical coil, the expansion or contraction of which is proportional to the temperature, is coupled direct to the dial pointer without the necessity of using a gearbox, so as to convert the movement of the light connecting shaft in the stem from the coil at the bottom into the horizontal movement necessary to move the dial pointer at the top.

The most robust of these "Heavy Industrial" designs are those fitted with $\frac{5}{8}$-in. diameter stems, but when greater sensitiveness to temperature transmission is desired a $\frac{5}{16}$-in. diameter stem should be used, with a stem not exceeding 24 ins. long in the case of the 2½-in. and 4-in. dial thermometers. With the 7-in. dial instrument, however, the head or dial portion would be somewhat too heavy for the light stem.

These instruments are suitable for almost any gas or liquid up to a temperature as high as 1050 degrees F., so that in many cases they are convenient for boiler flues, both before and after the economizer. So far as immersion in liquids is concerned, the only minor trouble is that, of course, no metal is resistant to every known liquid, but for most cases the standard practice martensitic iron (a grade of stainless iron) is suitable, although stainless steel or other metal for special corrosion-resisting conditions can be used if required.

FUEL ECONOMY AND PLASTICS.—In 1942, the British Plastics Federation was asked by the Secretary of Mines to send a deputation for the purpose of considering the formation of a Fuel Efficiency Committee for the Plastics Industry. As a result, the Council of the Federation appointed a committee consisting of eight members drawn from the various sections in the Federation.

This committee has now drawn up a memorandum, which is now in printed form, as a guide to its members in approaching the fuel problem effectively. The notes, which must be read in conjunction with the various bulletins issued by the Ministry of Fuel and Power, deals with the problem from the point of view of plastics under the following headings:—

1. Generation.
2. Utilization of Heat, Steam and Power.
3. Characteristic Processes of the Plastics Industry involving the use of heat and power.
4. Process Utilization of Heat.
   (a) General Insulation and Avoidance of Losses.
   (b) Steam Heating.
   (c) Heating by H.P. Hot Water.
   (d) Gas and Electric Heating.
5. General Heating.
6. Fuel Wardens.
7. Advice and Assistance.

THE INDUSTRIAL ALCOHOL COMMITTEE, under the chairmanship of Lord May of Weybridge, appointed by the Chancellor of the Exchequer to review the question of the grant of an allowance from the Exchequer in respect of industrial alcohol, which is at present regulated by Section 15 (2) of the Finance Act, 1921, announce that they are now prepared to receive any statements which individual concerns and associations interested as producers or users of industrial alcohol may desire to submit to them. Such statements should be made in the first instance in writing and addressed to the Secretary to the Industrial Alcohol Committee, Treasury Chambers, Great George Street, London, S.W.1. Concerns and associations will be informed in due course if the committee think it necessary for such statements to be supplemented by oral evidence.

THE MINISTRY OF SUPPLY has been informed that a representative of the U.S.A. Board of Economic Warfare is being sent to India to co-operate with the representative of the Ministry of Supply in the operation of the Indian Shellac Procurement Programme. The present system of public purchase of all shellac for importation into the United States and the United Kingdom will be continued and no change in the prices paid for shellac is contemplated. Defense Supplies Corporation, acting under the direction of the Board of Economic Warfare, will continue to be the sole buyer of shellac for importation into the U.S.A.

ENGINEERING BULLETIN. — The March, 1943, issue of Production and Engineering Bulletin contains many interesting features, among which the following are noteworthy:—Output Stepped-up by Transferring Work to Outlying Areas; Joint Production Committees in the Engineering Industry; Suggestion Box Schemes; Modern Practice in Factory Heating and Ventilation; Surface Hardening by Women; Girls Make Jigs, Tools and Gauges. There is also an excellent article on "The Training of Foremen."

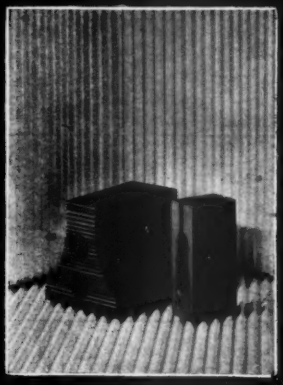
BRITISH XYLONITE CO., LTD.—At the annual general meeting an increase in the sales of the Group was reported, compared with the previous year. A final dividend on the ordinary shares of 7½ per cent. (making 10 per cent. for the year) was proposed. In his statement the chairman, Mr. C. F. Merriam, explained the effect of plastics on industry generally. He described how the industrialized nations were finding new and permanent uses and how manufacturers are realizing that a new class of materials has been added to the older class: metals, wood, glass, leather, textiles, etc

MAJOR STANLEY M. MOHR, O.B.E., M.C., M.I.E.E., managing director of the Micanite and Insulators Co., Ltd., has been re-elected chairman of the British Plastics Federation for the fourth year in succession.

MR. R. R. WILKINS, who has occupied the position of Director of Methanol and Formaldehyde in the Alcohol Control since September, 1940, has been appointed Director of Supplies (Special) in the department of the Director-General of Equipment and Stores, in the Ministry of Supply. He has now taken up his new appointment at Portland House, Tothill Street, S.W.1. Mr. Wilkins has for some time been dealing with reconditioned drums on behalf of the Alcohol Control, in addition to handling plastic raw materials, and will now deal with all containers which are the responsibility of the Ministry of Supply.

MR. GEORGE DUNCAN of the Barter Trading Corporation, Ltd., has been released to the Ministry of Supply and has been appointed to fill the vacancy in the Alcohol Control occasioned by Mr. Wilkins' transfer. Mr. Duncan has been associated for many years with Synthite, Ltd., who are well known as producers of formaldehyde.

PERMALI



Electrical Insulation

with strength where you need it

New Insulation Co., Ltd.,
Gloucester

ARE YOU USING THE Monsanto Plasticizer most suited to your requirements?

CHARACTERISTICS OF MONSANTO PLASTICIZERS

	Mol. Wt.	Colour and Form	Boiling Point	Cryst. or Melt. Point	Sp. G.	Refrac. Index	Evap. Rate 6ms/sq. cm/hr/ 100°C	Solubility in Water	Retentivity in N/C	Retentivity in Ac/C	Light Fastness in N/C	Light Fastness in Ac/C
★Tricresyl Phosphate	368	Colourless liquid	....	....	1.184/15.5°C	1.559/20°C	....	....	100 plus	0	Poor	....
Santicizer 8	199	Light amber liquid	....	....	1.188/25°C	....	0.0002659	0.13% at 23°C 0.213% at 48°C	100	90	Poor	Good
Santicizer 9	171	White granules	....	105°C	1.313/25°C	....	0.000053 at 65°C	1% at 34°C	25-30	25-30	Poor	....
Santicizer B-16	336	Colourless liquid	219°C/5 mm	Below—35°C	1.097/25°C	1.490/25°C	0.0000881	0.0012% at 30°C	100	20-30	Excellent	Excellent
Santicizer E-15	280	Colourless liquid	190°C/5 mm	20°C	1.180/25°C	1.498/25°C	0 0001106	0.0175% at 30°C	100	100	Excellent	Excellent
Santicizer M-17	266	Colourless liquid	189°C/5 mm	Below—35°C	1.220/25°C	1.504/25°C	0.000221	0.09% at 30°C	100	100	Excellent	Excellent
Dibutyl Phthalate	278	Colourless liquid	206°C/20 mm	—35°C	1.052/15.5°C	1.493/20°C	0.000221	0.001% at 30°C	100	Less than 20	Excellent	....
Diethyl Phthalate	222	Colourless liquid	295°C	—0.3°C	1.124/15.5°C	1.502/20°C	0.000617	0.058% at 30°C	100	100	Excellent	Excellent
Dimethyl Phthalate	194	Colourless liquid	282°C	0°C	1.196/15.5°C	1.515/20°C	0.001925	0.4% at 32°C 0.6% at 63°C	100	100	Excellent	Excellent
Diphenyl Phthalate	318	White powder	....	69°C	1.28/25°C	1.572/74°C	....	Insol.	....	20	Poor	....

★Tricresyl Phosphate has excellent Fire Retardation.

MONSANTO CHEMICALS LIMITED · RUABON · WREXHAM · DENBIGHSHIRE P.1107

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XVII.—Swelling in Relation to Permeability of Organic Membranes (Contd.)

Evaporation of Volatile Solvents from Solutions of Cellulose Ethers

IN studying the rate of the evaporation of solutions of cellulose ethers, Pakshwer and Mankash[242] were confronted with the necessity of a more detailed examination of the diffusion of vapours escaping from the surface of liquids through a film formed by the cellulose ether swollen in solvent. The velocity of the evaporation of nitrocellulose solutions for producing cine-films, lacquers and fibres is, to a great extent, determined by the vapour pressures of solvents over the semi-dry surface film.

As would be expected, neither the concentration nor the viscosity of the solution of the cellulose ether affects the initial speed of vaporization of the volatile solvents from a solution so long as there is no formation of the film. As soon as this moment arrives, the evaporation process progresses qualitatively in a different manner, since the governing factor becomes the speed of the vapour diffusion through the film.

The processes of evaporation from the surface of a liquid in air are very kindred to processes taking place in heat transfer from the surface of a heated body into the surrounding air.

In both cases the thermally agitated molecules moving on the surface must overcome the resistance of the boundary layer of air or a gas, although in evaporation there is a total escape of molecules from the surface of the vaporizing substance and a free movement of these molecules in the adjacent space; whereas in heat phenomena there occurs only the transmission of the vibratory motion from one molecule to another.

In both events, the absolute immobility of the surrounding air or gaseous medium is possible merely as a theoretical abstraction, while in practice this condition is never fulfilled, owing to convection currents (ascending and descending), in consequence of the difference in densities of vapour and air. Therefore, in both cases there are two feasible variants: (i) a relatively quiet medium, in which there takes place convection motion only, and (ii) the forced directed movement of the surrounding medium.

As soon as the film from the cellulose ether is formed on the surface of vaporizing fluid, the velocity of the evaporation slows down considerably. In contradistinction to the free vaporization in a motionless medium, the decelerating effect of the surface film is already detectable during the evaporation in an air current of even 2 per cent. solutions. This can be easily explained by the circumstance that the evaporating process in the current of air proceeds 5 to 10 times faster than in a motionless medium, and the diffusion of molecules through the film formed on the surface of the vaporizing liquid is unable to keep pace with the escape of molecules in the induced stream of moving air.

Diffusion of Vapours of Organic Solvents Through Cellulose Ether Films

Heretofore, the researches were mainly confined to the transfusion of water vapours through various films, notably by the studies of Taylor[243] and his associates, the investigations of Wray,[244] Edwards,[245] Wring,[246] and others.

However, the results obtained by dif-

ferent workers have seldom been concordant, and sometimes the data derived from one and the same study were very divergent. This lack of concordance may be explained by the circumstance that in the experimental researches no account was taken of the following three basic conditions:—

1. The velocity of air passing over the film surface drastically increases the rapidity of the diffusion of vapours. For this reason it is essential that all experiments should be conducted either in a perfectly still medium, or in the current of air under strictly defined conditions.

2. No proper attention has ever been paid to the " pre-history " of films, i.e., the method of their production, drying and storage, etc., although some investigators duly point out that these factors appreciably affect the speed of vapour diffusion through films. Fundamentally, these influences may be reduced to the action of swelling of the film under the test in the vapours of the diffusing substance.

Unfortunately, the correlation of experimental data with the swelling of films is totally absent in the works as cited.

3. A factor of paramount importance, apart from the film thickness, is also the distance from the mirror of the evaporation (correspondingly, from the surface of the absorber of vapours) to the surface of the films. The farther the surface of the vaporization from the film surface, the greater the thickness of the air layer through which the vapours have to diffuse.

Inasmuch as the air over the film remains in an absolutely motionless state, and the diffusion of vapours through the still air proceeds very slowly, the various authors have only studied the summary effect of diffusion through the film and the air.

With the view to correlating all the relevant factors bearing on the problem, Mankash and Pakshwer[247] have examined the diffusion of vapours of water, ethyl alcohol, ethyl ether, acetone and dichlorethane through the films derived from acetylcellulose, nitrocellulose and benzylcellulose. Parallel with this, they have also studied the kinetics and the

Table 1.[247]—The degree of swelling of cellulose ether films in the vapours of volatile solvents. The thickness of films h_2 = 0.0020 to 0.0025 cm. The surface of the film S = 20-40 cm. The temperature 16-18°C.

The film under the examination	Degree of swelling, per cent.			
	Acetone	Ether	Alcohol	Dichlor-ethane
Nitrocellulose, freshly produced, freshly prepared	125	50	30	40
After three days of storage	215	—	—	—
Drying for three hours, at 80°C.	125	30	19	—
Nitrocellulose from freshly produced ethylacetate	125	33	—	25
Drying for three hours, at 80°C.	150	90	26	—
Drying for ten hours, at 90°C.	80	—	—	—
Nitrocellulosef rom acetone, freshly prepared.	115	—	—	—
Drying for three hours, at 80°C.	135	48	22	—
Drying for ten hours, at 90°C.	75	—	—	—
Acetylcellulose from acetone, freshly prepared	85	12	12	40
Drying for three hours, at 80°C.	37	14	14	—
Acetylcellulose from dichlorethane, freshly prepared	75	—	—	—
After three days of storage	120	—	—	—
Drying for one hour, at 90°C.	115	—	—	—
Drying for three hours, at 90°C.	63	—	—	—
Benzylcellulose from dichlorethane, freshly made	13	8	—	—

capacity for swelling of the aforesaid cellulose ethers in the vapours of different substances.

The estimations of the degree of swelling have been made by means of measuring the gain in weight by the film during the period of 24 hours, in a desiccator over the vessel filled with a vaporizing and diffusing liquid. It should be remarked that for certain fluids and films the swelling in vapours proceeded with such an intensity that "flowing" took place.

The degree of the swelling of various films, expressed as percentage of the weight of the film, is given in Table 1; since in many cases of thick films the swelling does not cease even after two days, the tabulated data refer only to thin films.

The values as presented in this table demonstrate that the character of solvent (viz., alcohol-ether mixture, ethyl-acetate, acetone) has very little influence upon the degree of the swelling of the film, whereas the chemical nature of the film substance and absorbed vapours are of decisive significance. Thus, for example, the nitrocellulose films swell in acetone and in ether to a greater extent than the acetylcellulose films. It is also worth noting that the method of producing the film and the nature of solvent from which the film was derived affect not the degree of swelling, but the kinetics of swelling, i.e., the rate of increase in the weight of the film under the action of solvent vapours.

Experimental Procedure

The prolonged drying of films at 80 degrees to 90 degrees C. reduces their capacity for swelling, probably on account of the irreversibility of the swelling process of cellulose ethers in solvents. The diffusion of water vapour through nitrocellulose and acetylcellulose films was studied in the same desiccators, in which were made determinations of their degree of swelling. A beaker of given diameter was filled up to a certain level with the anhydrous caustic soda or dehydrated copper sulphate, after which it was hermetically sealed with the film to be examined and then placed over the water in the desiccator. The rate of diffusion, in grammes/per square cm./per second, has been computed from the gain in weight of the beaker during a definite interval of time.

The coefficient of diffusion was calculated according to the formula:—

$$K = \frac{1}{\frac{h_1}{\sigma_1} + \frac{h_2}{\sigma_2}} \cdot \frac{p_1 - p_2}{P} \cdot \frac{M.273}{22{,}400\,T}$$

Where: K denotes the velocity of the evaporation or the speed of absorption of vapours of the volatile liquid in grammes, per cub. cm., per second; σ_1—is the coefficient of vapour diffusion through air, in sq. cm., per second (at 0° C. and 760 mm. Hg., the coefficient of diffusion is σ_0); σ_2—is the coefficient of vapour diffusion through the film; p_1—the vapour pressure over the evaporating liquid; p_2—the vapour pressure, in mm. Hg., in the surrounding medium; P—the adjacent atmospheric pressure in mm. Hg.; M—the molecular weight of the vaporizing fluid, T—the absolute temperature during the evaporation (or absorption); h_1—the thickness, in cm., of the air layer, through which the vapours have to diffuse; h_2—the thickness, in cm., of the film under test, through which the vapours diffuse.

The experimental data on the coefficient of diffusion of water vapour through the films are shown in Table 2.

Diffusion of Vapours of Organic Solvents Through the Films

In investigating the diffusion of vapours of organic solvents through different films, the test-beaker of a given diameter was filled with a pure solvent and the beaker was hermetically closed at the top by the film under examination. In all experiments the vapour pressure of the diffusing vapour on the one side of the film, p_1, was equal to the saturation pressure at the test temperature, and the vapour pressure on the other side of the film, p_2, was assumed to be zero.

Table 2.[247]—The influence of thickness and ageing of the film upon the coefficient of diffusion of water vapours. The temperature 16° C.; $\sigma_1 = 0.250$ cm.²/sec.; $h = 5$ cm.; absorbent medium is caustic soda. All the films are freshly prepared.

Type of the film	Rate of evaporation, K	Thickness of film, h_2, cm.	Diffusion coefficient of the film, σ_2 = = cm.²/sec. 10^5
Water, distilled	0.0550	—	—
Nitrocellulose from alcohol-ether mixture	0.0330	0.0015	6.4
Nitrocellulose from alcohol-ether mixture	0.0270	0.0020	5.5
Nitrocellulose from alcohol-ether mixture	0.0218	0.0040	7.5
Nitrocellulose from alcohol-ether mixture	0.0170	0.0055	7.0
Nitrocellulose from alcohol-ether mixture	0.0155	0.0080	9.0
Nitrocellulose from alcohol-ether mixture	0.0100	0.0150	8.2
Benzylcellulose from dichlorethane	0.0022	0.0090	1.1
Benzylcellulose from dichlorethane	0.0022	0.0180	2.2
Acetylcellulose from acetone	0.0390	0.0015	10.2
Acetylcellulose from acetone	0.0270	0.0030	8.3
Acetylcellulose from acetone	0.0310	0.0090	33.3

After this, the beaker with liquid was placed into an air thermostat; the loss of weight due to the evaporation of liquid, its diffusion through film and height of the air layer from the level of the fluid to the membrane were noted.

The quantitative results of these experiments performed with various vaporizable media, such as ether, alcohol, acetone, dichlorethane, are illustrated by the data on the diffusion of ether through different films (see Table 3).

The films in all cases were produced under identical conditions: the nitrocellulose membranes were derived from " collaxylin " in the form of a 5 per cent. solution in the alcohol-ether mixture (2 : 3), or as the 5 per cent. solution in ethylacetate; the acetylcellulose films were made from commercial diacetate, with 58 per cent. of acetyl groups, in the form of the 5 per cent. solution in acetone, or in the mixture of dichlorethane with 20 per cent. of ethyl ether; the benzylcellulose films were obtained from the 5 per cent. solution of technical benzylcellulose in dichlorethane.

All the films thus prepared, prior to examination, were subjected to air drying for 24 hours.

Evaluation of Results and Conclusions

On the basis of the experimental data on the diffusion of vapours of water, ether, acetone, alcohol, dichlorethane, through the nitro-, acetyl- and benzyl-

Table 3.[247]—The influence of film thickness upon the diffusion coefficient of ether vapours through membranes. The temperature 16°C. All the films are freshly prepared.

Type of film	Velocity of evaporation, K=gm./ cm.²/sec.10^5	Thickness of film, h_2, cm.	Coefficient of diffusion through the film, σ_2= cm.²/sec.10^5
Ethyl ether ..	7.8	—	—
Nitrocellulose from alcohol-ether mixture	0.54	0.0010	0.34
Nitrocellulose from alcohol-ether mixture	1.10	0.0020	1.20
Nitrocellulose from alcohol-ether mixture	0.90	0.0050	2.30
Nitrocellulose from ethylacetate ..	1.49	0.0015	1.40
Nitrocellulose from ethylacetate ..	1.78	0.0020	2.30
Acetylcellulose from acetone	0.38	0.0005	0.11
Acetylcellulose from acetone	0.36	0.0011	—
Acetylcellulose from acetone	0.76	0.0040	1.5
Benzylcellulose from dichlorethane ..	1.95	0.0020	2.8
Benzylcellulose from dichlorethane ..	1.05	0.0050	3.1

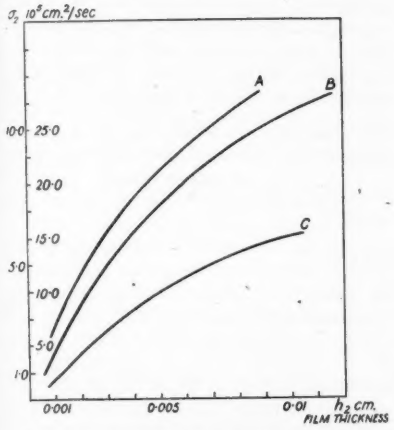


Fig. 1.—Variation of the diffusion coefficient with change of film thickness of acetylcellulose. A, for vapours of ether; B, for acetone vapours; C, for alcohol. Note: the scale of the σ_2 ordinate for the curve of the ether diffusion is reduced 2.5 times compared with that for acetone and alcohol.

cellulose films, the coefficients of diffusion, σ_2, have been computed for various membranes from 0.0005 to 0.0200 cm. thick.

A.—As the Tables 1-3 indicate, the coefficient σ_2, in all cases, grows with the increase of the film thickness, which is in perfect agreement with the results of experiments carried out by Taylor.[243]

The increase of the coefficient σ_2 in the diffusion of acetone, ether, and ethyl alcohol through the film freshly prepared from the acetylcellulose, derived from the acetone solution, is depicted in Fig. 1.

A similar dependence is obtained in the diffusion of vapours of volatile liquids through the benzyl- and nitrocellulose films.

B.—The next characteristic result revealed by the investigation of the coefficient σ_2 is the variation of its value in time. As may be seen from the Table 4, in most cases, the coefficient σ_2 decreases with time, falling, for example, in the diffusion of acetone through the acetylcellulose film during the period of 12 days, 2 to 2.5 times. This observation is in complete accord with the data of Wray,[244] as well as those of Edwards[245] and Wring.[246]

In certain instances, for example, in the diffusion of acetone through benzylcellulose, of ethyl-ether through acetylcellulose, ethyl alcohol through the nitrocellulose, and water through the nitro- and acetylcellulose, the coefficient σ_2 does change with time, and even displays a tendency to increase.

It is of interest to note that the degree of swelling of the aforesaid films in the vapours of the above-named volatile liquids is also smaller than in other fluids, as is shown in Table 1.

Thus, apparently, in the total absence

Table 4.[247]—The Variation of the Coefficient of Diffusion of Solvent Vapours through Films with the Time. The Temperature 16°C.

Type of film	Diffusing vapours	Thickness of film, h_2, cm.	Diffusion coefficient, σ_2, in cm.^{2}/sec. 10^6				
			After 1 day	After 2 days	After 3 days	After 6 days	After 12 days
Acetylcellulose from acetone	Acetone	0.0020	4.6	—	3.1	2.3	1.5
Acetylcellulose from acetone	Acetone	0.0070	9.0	—	—	—	3.5
Acetylcellulose from acetone	Acetone	0.0160	16.6	13.0	—	—	—
Nitrocellulose from ethylacetate	Acetone	0.0020	3.5	—	—	—	2.2
Nitrocellulose from alcohol-ether mixture ..	Acetone	0.0035	8.0	—	—	—	6.4
Benzylcellulose from dichlorethane	Ethyl ether	0.0020	2.0	2.0	—	—	—
Benzylcellulose from dichlorethane	Ethyl ether	0.0030	2.3	1.8	—	—	—
Benzylcellulose from dichlorethane	Ethyl ether	0.0050	2.5	—	1.8	—	—
Nitrocellulose from ethylacetate	Ethyl ether	0.0015	1.4	—	0.9	—	—
Nitrocellulose from alcohol-ether mixture ..	Ethyl ether	0.0020	1.8	1.1	1.0	—	—
Nitrocellulose from alcohol-ether mixture ..	Ethyl ether	0.0050	2.8	1.8	1.7	—	—
Acetylcellulose from acetone	Ethyl ether	0.0030	0.45	—	0.5	—	—
Nitrocellulose from ethylacetate	Water	0.0020	—	—	12.0	15.0	—
Nitrocellulose from alcohol-ether mixture ..	Water	0.0025	—	—	10.0	10.5	10.5
Nitrocellulose from acetone	Water	0.0015	—	—	8.3	9.4	7.0
Acetylcellulose from acetone	Water	0.0070	—	—	28.0	36.0	21.0

of swelling, or with slight swelling of the film in the vapours of a diffusing substance, the size of the pores in the film does not alter with the lapse of the time, and, consequently, does not change the value of the diffusion coefficient, σ_2.

In the event of an appreciable swelling of the membrane in the vapours of a diffusing liquid, the film is densified with time, and the diffusion is impeded, i.e., the coefficient σ_2 is diminished.

C.—As yet, no definite relationship has been deduced between the degree of the swelling of the film under the action of the diffusing vapours and the value of the coefficient σ_2, although a connection, doubtless, should exist. Inasmuch as the degree of swelling, as presented in Table 1, depends upon a whole series of factors, for instance, on the temperature of swelling, the length of time and the conditions of drying (for example, on the stretching in drying), its influence is, apparently, felt most of all on the speed of attaining the equilibrium of the diffusion through the film, i.e., in the initial period. In the above-described experiments, the coefficient σ_2 has been determined after the lapse of 24 hours, that is, after the establishment of almost complete equilibrium, and, in consequence, the degree of swelling has affected very little the value of the coefficient σ_2.

D.—The nature of the solvent does not influence the value of σ_2; this is shown by Table 2 on the water diffusion through the nitrocellulose films of the identical thickness, derived from ethylacetate, acetone, and the alcohol-ether mixture, as well as the diffusion of organic vapours, such as acetone, ether, etc. But the method of producing the film strongly affects the value σ_2, which decreases with time and with the temperature of drying. This observation is in conformity with the diminution of the diffusion coefficient σ_2 in time, as recorded in Table 4.

The Swelling of Films as an Indirect Method of Determining the Relative Sizes of Micelles

The treatment of the factor of swelling would not be complete without mentioning the role it can play in assessing the relative dimensions of micellar complexes, as has been ably demonstrated by Voskresensky[248] in Russia.

The most accurate and modern means for determining the absolute size of crystallites and micelles is the Reontgenographic method. Nevertheless, having regard to the concept of the discontinuity of the structure of matter, the information on the relative sizes of micelles may be obtained by studying the swelling of thin films in inert media. In the process of their swelling there should take place an alteration of the linear dimensions of the films, the value of which must depend on the shape and the relative dimensions of elementary particles constituting the substance, be they micelles, crystallites or crystals.

In the course of penetration of the liquid into the interstices, the intermicellar spaces, the distance between micelles should vary and, subject to the shape and arrangement, their linear dimensions will change.

Let us consider a rectangle with the sides A and B, composed of parallelograms, with some ratio of their sides, a and b, for example, 5 : 1, as illustrated in Fig. 2, Diagram 2.

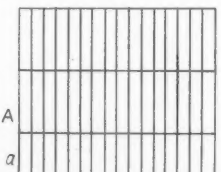


Diagram 1.

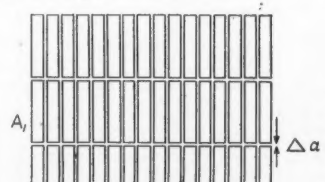


Diagram 2.

Fig 2.—The sides of the elementary parallelograms composing the rectangle AB, are in the ratio a:b = 5:1. AB is formed by distension of the units by the interval Δa.

Let us presume that these elementary parallelograms are distended by Δ a, as portrayed in Diagram 2 of Fig. 2. It is clear that the sides thus formed in Diagram 2 will be larger than the sides of Diagram 1, and the relation, $\frac{A_1-A}{A} \cdot 100 = p$, is the per cent. increase in the height, while the relation, $\frac{B_1-B}{B} \cdot 100 = q$, is the per cent. increase of the width. The question arises whether it is feasible to obtain any information on the ratio of sides of the elementary parallelogram from the ratio $\frac{q}{p}$ or $\frac{p}{q}$? The discussion which follows will show that under certain conditions this is quite possible.

Let n denote the number of elementary parallelograms arrayed in height, and m their number in the width. Then the difference A_1—A will be formed by (n—1) Δ a, and B_1—B by (m—1) Δ a, and in the first approximation it is permissible to state that the relationship $\frac{B_1-B}{A_1-A}=\frac{m-1}{n-1}=\frac{a}{b}=\frac{q}{p}$.

In conformity with the case as depicted in Fig. 2, let us tabulate its values as follows:—

Table 5.[248]

m	1	10	100	1,000	10,000	100,000	10^{X-1}
n	1	2	20	200	2,000	20,000	2.10^{X-1}
m—1	0	9	99	999	9,999	99,999	10^{X-1}
n—1	0	1	19	199	1,999	19,999	$2.10^{X-1}-1$
$\frac{q}{p}=\frac{m-1}{n-1}$	0	9	5.2	5.02	5.002	5.0002	$5.2 \times 10^{-(X-1)}$
$\frac{a}{b}$	5	5	5	5	5	5	5
Difference $\frac{q}{p}-\frac{a}{b}$	—	4	0.2	0.02	0.002	0.0002	$2 \times 10^{-(X-1)}$

From the Table 5 it may be observed that, with a certain regularity of the elementary parallelograms, as their number increases, the relation $\frac{m-1}{n-1}=\frac{B_1-B}{A_1-A}$ approaches the ratio $\frac{a}{b}$ or $\frac{q}{p}$. With an infinite increase of the index X, the difference $2.10^{-(X-1)}$ tends to diminish to zero, and the value of the relation $\frac{m-1}{n-1}$ approaches the ratio $\frac{a}{b}$ as a limit.

As may readily be seen, by arranging the elementary parallelograms in the order, as is shown in Table 5, the figure thus formed will be a square.

Consequently, the prime condition is that in order to derive the true results, or their very close approximations, it is necessary to have a square-shaped configuration. The next condition is that the elementary figures, forming the square should be arranged in parallel or, alternatively, symmetrical fashion. Should elements, composing the square, be distributed in a chaotic way, then the above regularity does not hold true.

Thus, by cutting from any film a square and allowing it to swell in a liquid, in which the film only swells, but does not dissolve, and by observing the increase of its linear dimensions, it is possible to obtain the information as to the relative magnitude of the elementary bodies constituting the film, with one basic proviso, that the great majority of these structural units are situated symmetrically along the axes of co-ordinates.

If we cut from the substance a cube, then by observing the change of its sides in the course of the swelling, we are in a position to determine the largest axes of its constituent elements.

Hence it follows that the process of swelling may serve as an indirect method for the evaluating of relative magnitude of elementary bodies (viz., molecular complexes, micelles) composing a given substance.

Clearly, this method is of special interest to the research worker in his dealing with high polymeric organic compounds, and particularly with the cellulose.

To examine, for instance, the hydrate-cellulose by the method of swelling, the most convenient material is that of a film which can be prepared either from viscose or from some other suitable source.

As was mentioned before, the requisite condition for obtaining the correct results is that the distribution of micelles in the material under the investigation should not be at random, but arranged parallel, as far as possible, to one of the co-ordinate axes.

The films derived from viscose meet these conditions in an appreciable measure, since all their properties testify that cellulose micelles are arranged in them not chaotically but in oriented manner.

For example, it is a highly characteristic fact that the strength of the films in the two directions at right angle to one another is not identical, namely, the tensile strength in the longitudinal direction (along the motion of the film in the course of its manufacture from the plant) is greater than that across. But contrariwise, the intermicellar distances are larger in the direction perpendicular to that of the longitudinal way.[249]

Furthermore, the optical properties, such as the double refraction of light rays, provide the testimony that a film is built up of micelles, distributed, in most cases, in an oriented fashion. Finally, the same fact is corroborated by the results of X-ray analysis of films.

The convenience in application of the films in this study also consists in that a regular orientation of micelles can be obtained by means of a slight stretching of the test film in the longitudinal direction.

On immersion, the films swell in water, glycerine solution, ethylene glycol or formamide.

The principal factors inducing the swelling of the film are:—

(a) Capillary forces.

(b) Adsorption forces.

The first to go into action are capillary forces. According to available data, the intermicellar spaces, which at the same time function as capillaries, are in magnitude of the order of 10^{-4} to 10^{-5} mm. At the next moment the capillary forces are augmented by the forces of sorption.

In the opinion of Herzog,[250] in swelling of cellulose in water, the latter in large proportion is combined with the cellulosic substance, and even enters into a micelle, particularly that of the regenerated cellulose.

Sheppard and Newsome,[251] examining the sorption of water vapours by cellulose, came to the conclusion that in this process the union of water is effected through the free hydroxyl groups of the cellulose molecules, i.e., those which stand out on the surface of a molecule. If each hydroxyl of a $C_6H_{10}O_5$ group is free to combine with one water molecule, then the cellulose should be capable of adsorbing 33 per cent. of water, assuming that in the cellulose there are only three free hydroxyls. This value is readily obtained by the simple calculation:—

$$\frac{\text{M. wt. of } 3H_2O \times 100}{\text{M. wt. of cellulose}} = \frac{5,400}{162} = 33\tfrac{1}{3}$$

However, natural cellulose adsorbs only 16 to 18 per cent. and hydrated cellulose 23 per cent. Since the adsorption of hydroxylamine depends on the surface, from the foregoing values it follows that the surface of the hydrated cellulose is nearly 50 per cent. greater than that of the original cellulose; nevertheless, not all the hydroxyl groups are free. Whence it may be inferred that the micelle of the hydrated cellulose in magnitude and shape should be distinct from that of the original cellulose.

As a result of the increase of the inner surface, the ratio of the two principal axes in the hydrated cellulose micelle

on ne passe pas

THOUGH Custom may cry Halt, the order of the day is Forward. In modern industry, men and women of imagination, undeterred by the doubts of the timid, are pressing on towards new ideas and methods.

Of this dynamic spirit Simmonds Aerocessories is at once the symbol and the servant. The Simmonds Organization is geared to the achievement of maximum output without loss in quality; the Simmonds products in all fields are fulfilling a high vocation in conserving the Nation's time, material and man-power. Let Simmonds be your ally in the great advance.

SIMMONDS

The Creative Impulse in

AERONAUTICAL, INDUSTRIAL & MARINE

Construction

THE SIMMONDS NUT · PINNACLE NUT · SPIRE NUT
SIMMONDS GAUGES, INSTRUMENTS AND CONTROLS
FRAM OIL & ENGINE CLEANER

SIMMONDS AEROCESSORIES LTD.
GREAT WEST ROAD, LONDON

A COMPANY OF THE SIMMONDS GROUP

LONDON, MELBOURNE, PARIS, NEW YORK.

P.15

—too tough to split

Neither strain nor age can split Jicwood, much less an axe. It is even too tough to warp. Jicwood is a compressed wood of extraordinary strength and hardness, yet easily workable. Characteristics are akin to metal, specifically lighter and cannot fatigue; yet the refinements of wood are retained. It has proved invaluable for aircraft propeller blades, jigs, bearings, rollers, shuttles, silent gears and many other products where strength with lightness is required. It can be made in various grades and combinations: e.g., Grade 138; Tensile 45,000 lbs. per sq. in.; Shear 7,000 lbs. per sq. in.; Specific gravity 1·38.

We shall be pleased to send fuller details upon knowing your requirements.

JICWOOD

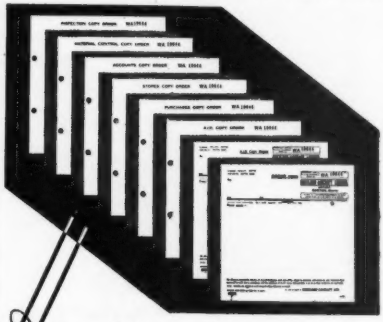
JICWOOD LTD., GROSVENOR GARDENS HOUSE, LONDON, S.W.1
Telephone: VIC. 4527-8. Telegrams: Jicwood, Sowest, London.

FOR *any* STYLE...

of CARBON COPY BOOKS or FORMS

it's LAMSON PARAGON

(BRITAIN'S BIGGEST FORM PRINTERS)



Harness the maximum power of Carbon-paper to your

PRODUCTION EFFORT

by using only

LAMSON PARAGON Carbon Copy PRODUCTIONS

IT'S all one to Lamson Paragon whether you need Precision Forms for Tabulating machines; continuous Fanfold or Interfold Forms for Billing machines or Typewriters; Pack Forms for Autographic Registers; Unit Sets with or without ready-interleaved carbon; ready carbonized forms or simple carbon-copy docket books.
In *every* kind of numerical carbon-copy Business Forms LAMSON PARAGON provide the BEST — the most skilfully planned, the most serviceable product you can buy — in books, pads, sets or continuous lengths.

LAMSON PARAGON
THE CARBON COPY FORM SPECIALISTS

LAMSON PARAGON SUPPLY CO LTD · "A Ministry of Co-ordination" · PARAGON WORKS, LONDON E16 QUEENS HOUSE, 28 KINGSWAY WC2 · BRANCH OFFICES IN BIRMINGHAM · BRISTOL · GLASGOW · LEEDS LIVERPOOL · MANCHESTER · NEWCASTLE-ON-TYNE · ASSOCIATED COMPANIES THROUGHOUT THE EMPIRE AND THE USA REPRESENTATIVES EVERYWHERE

Table 6.[248]

The type of Viscose film	Dry		Swollen		Dimensional increase per cent.			Ratio of the increase of length to width*
	Area, mm.	Thickness, mm.	Area, mm.	Thickness, mm.	Length	Width	Thickness	
"Cellophane," coloured, Du Pont, U.S.A. ..	50×50	0.025	54.3×50.8	0.0425	1.6	8.6	80	1:5.4
Type made by Kalle and Co., Germany	50×50	0.07	54×50.06	0.145	1.2	8.0	107	1:6.6
Type made by Maurer, Italy	50×50	0.02	53.8×50.8	0.04	1.5	7.6	100	1:4.75
Viscacelle	50×50	0.025	51.25×50.25	0.035	0.5	2.5	40	1:5
Cilfran	50×50	0.02	52×50.3	0.03	0.6	4.0	50	1:6.6

* Average 1 : 6.

should be smaller than that of the native substance. Thus, Herzog's views are, in a certain measure, finding the corroboration in the work of Sheppard and Newsome.

The hydrated cellulose film, prepared from viscose, on being immersed in water at 17 degrees to 18 degrees C., imbibes up to 150 per cent. of water.

Therefore, the largest bulk of water absorbed by the film is that part which fills the intermicellar spaces.

The swelling of the film is accompanied by its dimensional increase in all the three directions. This is clearly demonstrated by the data of Table 6, on the variations of the linear dimensions of the viscose films of different types, the swelling of which in water has been examined at 17 degrees C. for one hour.

From Table 6 it is seen that the average ratio of the increase of the length and the width = 1 : 6, fluctuating within the limit of $\pm$ 1.

Appreciably greater divergencies occur in the increase of thickness, where the values differ as much as 2.5 times (from 40 to 107 per cent.). Without going into the explanation of the causes of this phenomenon, it should be merely remarked that magnitude and the direction of the third axis of the elementary crystallite (micelle) of hydrated cellulose in the case of the film is not characteristic, and as the object under consideration is not a cube, but essentially two-dimensional, it is evident that, in the circumstances, it is impossible to determine the relative magnitude of this axis.

A far greater interest attaches to the fact that, by the method of swelling, the ratio of the two fundamental axes of the crystallite of hydrated cellulose = 1 : 6, i.e., here we have the confirmation, in an indirect way, of the stretched shape of the micelle, and, at the same time, we find corroboration of the correctness of the method.

To arrive at a comparison of the results derivable by the Roentgenographic method and by means of swelling, the values obtained by the latter require to be checked and corrected with regard to the arrangement of micelles. The optical investigations allow us to make the postulate that, approximately, from $\frac{2}{3}$ to $\frac{3}{4}$ of micelles are distributed in an oriented manner, i.e., parallel to the greater axis, and only about $\frac{1}{4}$ to $\frac{1}{3}$ of them are situated at random. Introducing the correction in this case, the ratio of the principal axes will be 1 : 8.5, i.e., the value, which is already very close to the relation as given by the X-rays method.

But, as has been indicated earlier, taking into account the data of Sheppard and Newsome, it is legitimate to assume that the main axes of the micelle of hydrated cellulose will differ from those of natural cellulose, and the aforesaid

axes ratio 1 : 8.5 should correspond to the true situation in the first approximation.

Omitting here the details of the matter, it suffices to state that the method of swelling of films, supplemented by optical determination of the degree of the orientation of the micelles, can be a useful tool for the estimating of their relative sizes, and furnishes values, which are correct in the first approximation.

It is also important to note that this method may be utilized as a means of control for such substances as the cellulose films prepared from viscose, since the variation of the linear dimensions of the membrane can characterize both the technical régime of the treatment and, partly, the raw material.

The Peculiarities of Swelling of Cellulose Films in Water

On account of the adaptability of cellulose film and sheet materials to the increasing needs of industry, it is important now to inquire into their susceptibilities to swelling. A thorough understanding of the latter phenomena is likely to yield a much higher reward to the investigator than mere tabulation of the transitory test values for the products available on the market; it will surely lead to the synthesis of improved substances with properties able to withstand more rigorous service conditions, such as greater resistance to moisture, humidity, and other deleterious factors.

Of the cellulose film and sheet stock particularly interesting are those produced from viscose, as typified, for example, by " Cellophane " and similar material, the use of which offers numerous possibilities and distinct advantages. For instance, in the leather and allied industries, it is ideally suited for many applications, and, in fact, it is the basic substance entering into the composition of artificial leather from viscose.

What is known under the trade name of " Cellophane " represents a transparent cellulose film, derived, like the rayon, from viscose, i.e., by alkaline solution of sodium xanthogenate.

Therefore, the study of the main factors, which influence the swelling of viscose film and sheet materials in water, are of paramount importance; of special interest are those of the factors that are conditioned by a certain difference in the method of production of given films, and the detection of which will enable the technologist to regulate the manufacturing process in the desired direction.

A comprehensive treatment of this problem we find in the works of Morozoff,[252] who, since 1933, has conducted a series of systematic studies on the subject at Moscow Laboratory of Physical and Colloidal Chemistry. Morozoff and his co-workers have succeeded in demonstrating the influence of various methods of thermal and chemical treatment of the viscose sheeting materials, upon their swellability in water, and the means by which it is possible to reduce in a maximum measure their propensity for swelling. The last-named effect is, clearly, of particular value to the technology of the synthetic leather from viscose.

It has been known for some time that, for example, a rapid and intensive drying reduces the swelling capacity of the cellulose fibres.[253] The drying at high temperature levels should, obviously, be included into the same category. From the technology of artificial (viscose) silk it is known that, as the intensity of the mechanical factors of treatment of the semi-finished thread rises its ability to swell decreases.[254]

If the application of the mechanical treatment of cellulose sheeting materials under laboratory conditions meets with some difficulties, then an attempt to explore the thermal factors of the treatment affords a greater promise of achievement.

Similarly with the purely chemical methods of treatment of synthetic leather compositions. In this respect two methods of procedure are open. First, to impregnate the viscose sheeting material with a solution of an inert substance, and then, by means of chemical reaction, to obtain in the thickness of the sheet, in its pores, the precipitate of a substance insoluble

in water, which through the sealing of capillaries, thereby in the purely mechanical manner, would prevent the ingress of water, and, consequently, that of swelling. With this object in view, borrowing from the practice of textile manufacture, the viscose specimens were subjected to impregnations with solution of aluminium acetate, with the subsequent "steaming," to effect the hydrolysis of the formation of the precipitate of the hydrate of oxide.

It has been found that specially efficacious is the action of such a treatment in estimating of the swelling by its deformation value. In the latter event the viscose sheets reveal, during the swelling, the dimensional increase in area at less than 10 per cent. (instead of 25 to 30 per cent. for the untreated materials).

The Influence of the Maturity of Viscose on its Swelling in Water

The present-day ideas on the process of maturing of the viscose supports the theory that the structure of viscose gels and of cellulose films derived from them will not be identical, and depend upon the degree of maturity of the parent viscose.

On the basis of these considerations it was possible to expect also a different behaviour in the swelling of various films.

The careful experiments with the viscose of different degrees of maturity and the rôle of this factor in the swelling of viscose films in water at various temperatures showed them to be in conformity with the above view.

The swelling of films has been examined by (a) the gain in weight method and (b) estimating the heats of swelling. The first method supplies data on the total quantity of water absorbed by the gel in the course of swelling, and the second gives the value of the hydrate water, i.e., combined by forces of a chemical nature. The studies have been carried out with films, prepared from viscose at the Experimental plant, the Moscow Synthetic Fibres Research Institute, and part of the experiments was repeated with cellulose films regenerated from viscose, used for the production of leather compositions, at the Central Scientific Research Institute of Leather Industry, Moscow.

Swelling and Hydration

The constitution of the molecule sodium-xanthogenate, according to the Mayer and Mark's[255] scheme of cellulose structure, may be regarded as the sulphurized molecule of the cellulose, built up from the glucose residues, mutually combined into a chain of fundamental valencies.

The solubility of sodium-xanthogenate of the cellulose in water is explained by the fact that in the process of xanthogenation there takes place a weakening of bonds between the chains of the primary valencies in the micelle of the alkali-cellulose. Consequently, viscose is a solution which contains, mainly, not the micelles of sulphonated cellulose, but the molecules (separate chains of the principal valencies).

The maturing of the viscose is a process partly of a chemical nature, consisting of the hydrolythic splitting off of the xanthogenate into cellulose and a series of simple inorganic substances. However, in contradistinction to the ordinary hydrolysis, this process is of the irreversible character, and leads to the complete decomposition of xanthogenate.

Furthermore, the maturing of viscose is a phenomenon of the colloidal-chemical order, and should be considered as the ageing of the colloid. In maturing or in the process of ageing of the viscose, dehydration of the dispersion phase is observed; this favours the creation of bonds between feebly hydrated particles of the cellulose, and results in the gelation of solution.

The aforesaid conception of the xanthogenate and the mechanism of maturing of its solutions, permits the assumption that the structure of viscose gels and of the films obtained from them (viz., "Cellophane" and the like) is dissimilar, depending on the degree of maturing. On the same grounds, the content of admix-

tures of low molecular fractions of the cellulose, the so-called hemicelluloses, should be different. The amount of these fractions in the films from the "old" viscose should be larger, since the products of the hydrolysis of cellulose accumulate with time. This is confirmed by the experiments with repeated swelling.

The observed growth of the capacity to swell in the viscose films, as the time of the maturing of the initial viscose lengthens, is, therefore, a function of the content of low molecular admixtures of the decomposition of cellulose (determined usually by the "copper number").

Moreover, the structure of the viscose film formed by the interlacing of more or less oriented chains of the primary valencies of the cellulose molecules also plays a part in the swelling.

Thus, the process of swelling of viscose films represents a phenomenon of a very complex character, which depends upon the peculiarities of each given specimen (e.g., the structure of admixtures, etc.).

Appraisal of the Results

The theoretical considerations of the phenomenon of swelling of viscose films, confirmed by experiments, led their authors to formulate the following conclusions:—

A.—It has been established that there is a definite dependence of the maximum value of the swelling of viscose films on the duration of maturity of the parent viscose. As the maturity period lengthens there is observed a clearly defined tendency towards increasing swelling.

For example, the film, prepared from viscose, matured for two days, in the course of its swelling in water, at 25 degrees C., shows a gain in weight of 50 per cent., whereas the film made from viscose of the 12 days' maturity, subjected to swelling under identical conditions, absorbs 70 per cent. of water, calculated on the weight of the dry substance of cellulose.

B.—In the general tendency of the rising of the curve of swelling, approximately midway of this performance curve, there is a point indicating a certain minimum value and characterized by its invariability. The presence of this minimum has been ascertained in the behaviour of cellulose films derived from different viscoses.

C.—On being subjected to repeated experiments of swelling, the viscose films show that their ability to swell diminishes. In this case there is manifestation of the flattening of the dependence of the swelling upon the degree of the viscose maturity, which was in a highly accentuated manner revealed in the course of the preceding experiment with swelling.

D.—The dissimilar intensity of swelling of the various films is related to a different content of the products of the hydrolytic decomposition of cellulose. The greater the maturity of the viscose, the larger the proportion of the decomposition products within the films obtained from the viscose.

E.—By means of measuring the heats of swelling, it has been established that about one-third of the water absorbed by the viscose film in the process of swelling is bonded by forces of a chemical nature.

(To be continued.)

REFERENCES

(247) *Mankash and Pakshwer; Jl. Phys. Chem., XI*, 3, 1938. **(248)** *Voskresensky; Jl. Appl. Chem., VIII*, 128, 1935. **(249)** *Ind. Eng. Chem.*, 21, 405, 1929. *Kunststoffe*, 10, 11, 12, 1929. *Koll. Z., XI*, 2, 240, 1932. **(250)** *Herzog; Soc. Dyers Col.*, 46, 175, 1930. **(251)** *Sheppard and Newsome; Jl. Phys. Chem.*, 34, 1,158, 1930. **(252)** *Morozoff and Associates; Jl. Appl. Chem., VI*, 5, 879, 1933; *VII*, 7, 1,240, 1934. **(253)** *Fotieff*; "*Improved Cellulose*," 1931, *Moscow*. **(254)** *Faust*; "*Rayon*," 72-73, 1931, *Moscow*. **(255)** *Mayer and Mark; Zts. phys. Chem.*, 2, 140, 1929.

Discussion Group Meeting

The next meeting of the N.E. London Supervisors' Discussion Group will be held on April 20, in the South-West Essex Technical College, Walthamstow. The following problems will be discussed:—

1. Size of Shop or Group under supervision.

2. Relation of Foreman to Charge-hands.

MUZZLED . . .

That's how we feel about our present activities, but soon, no doubt, we shall be able to place the knowledge gained during our silence at the service of private enterprise. In the interim, we, like Dobbin, are pulling our weight and making the wheels turn faster and faster towards the new age.

Our Advisory Panel of Technicians and also our extensive research laboratories are always ready to consider individual Manufacturers' problems.

De La Rue Plastics LTD.

Telephone Larkswood 2323

AVENUE WORKS · WALTHAMSTOW AVENUE · LONDON · E.4

GRINDING OF PLASTICS

The MASSON ROTARY CUTTER reduces all kinds of Plastic materials and synthetic rubber to granular form, with complete freedom from dust. Any degree of granulation obtainable.

LOW H.P. HIGH OUTPUT

THE MASSON ROTARY CUTTER

BLACKFRIARS ENGINEERING COMPANY, LTD.
Blackfriars House,
New Bridge Street, London, E.C.4 *Tel.: CENtral 6383*

Tenaplas

EXTRUDED PLASTICS

Although mainly used at the present time for Chemical and Electrical Insulation the Tenaplas Process of Extrusion can be utilised with great advantage in many other branches of industry.

Our Service is at the disposal of all manufacturers interested.

TENAPLAS LTD. Head Office, 7 PARK LANE, LONDON, W.1.

COURTAULDS PLASTICS

CELLULOSE ACETATE
CELLULOSE ACETATE SHEETING
CELLULOSE ACETATE FILM

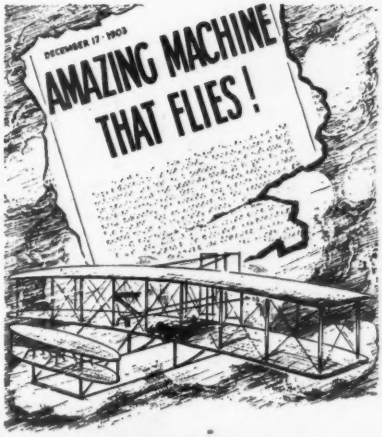
COURTAULDS LTD.
Foleshill Rd., Coventry. Tel.: Coventry 88771

EST. 1899

CRYSTALATE

MAINTAINING THE TRADITION OF 44 YEARS EXPERIENCE IN THE ART AND PRACTICE OF PLASTIC MOULDING AND TOOLMAKING

TONBRIDGE, KENT
PHONE: HADLOW 233/4



But what was the Wright Brothers' Production Problem?

Just this: to make one aircraft— only one — that would fly.

Design — cost — time . . . . . all relatively unimportant.

When an invention has been proved and improved there arrive ultimately the problems of production —in our time the master problems. These problems are solved by discovering what should be, what is, and what can be done in terms of factory inflow, throughflow and outflow. Kardex accomplishes these tasks simply, smoothly and with less clerical effort.

★*PRODUCTION CONTROL, by A. R. Jackson. The above booklet presents an outline of production control problems and practical solutions. Sent on application for 1/- post free to Dept. P.I. Kardex systems are available only to essential industries.*

KARDEX

VISIBLE CONTROL SYSTEMS
1, NEW OXFORD ST., LONDON, W.C.1
Tel.: CHANCERY 8888

SYNTHETIC
RESIN
PAPERS
Impregnated and coated for the manufacture of laminated SHEETS & TUBES

SAMUEL JONES & Co. Ltd
16-17 NEW BRIDGE STREET, LONDON E.C.4
Phone CENtral 6500

PROGRESS IN PLASTICS

In recent years there has been great development in the plastics industry. Were it not for the tremendous strides made in peace-time, much of the war effort would not be possible, particularly in aircraft production. When peace returns plastics will play an ever-increasing part in the needs of mankind. In the meantime, if a job crops up, will you discuss it with us?

SOUPLEX

SOUPLEX LTD., MORECAMBE, LANCS.

ARDUX is a quick-setting adhesive for mouldings and laminated plastics.

ARDUX
WELDS PLASTICS
APPROVED for AIRCRAFT USE
MADE BY THE PIONEERS of SYNTHETIC ADHESIVES
AERO RESEARCH LIMITED
PHONE SAWSTON 167-168 DUXFORD, CAMBRIDGE

No preparation of the surface is necessary. Ardux is doing a valuable job in eliminating wastage and reduces machining of aircraft components. Ardux can help you in your problem; may we show you how?

REDUCE NOISE
INCREASE OUTPUT

Equip your workers with the appliance tested and proved by more than 25 years' successful service:—

the
MALLOCK-ARMSTRONG
EAR DEFENDER

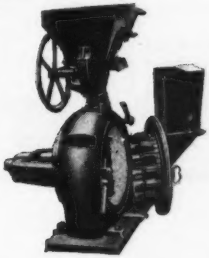
39, Victoria St., London, S.W.1. Phone: ABBey 7113

GARDNER'S

A NAME THAT MEANS A "GOOD DEAL"

'Rapid' Combined

GRINDER & SIFTER



GARDNER'S high reputation and experience of close on a century is your guarantee of fine performance and workmanship. The "Rapid" Combined Grinder and Sifter fully bears out their highest traditions. It grinds and sifts simultaneously, so that separate dressing is unnecessary. Fitted with interchangeable screens, cleaning is quick and simple. Will operate for years without trouble or breakdown. Can be supplied direct coupled to motor.

Write for catalogue

WM. GARDNER & SONS (Gloucester) LTD
BRISTOL ROAD, GLOUCESTER
Phone: 2288 (3 lines). Grams: "Gardner, Gloucester."

LONDON: 19, GRAY'S INN CHAMBERS, 20, HIGH HOLBORN, W.C.1. *Phone: Chancery 7347*

GARDNER'S MACHINERY for GRINDING • SIFTING • POWDER DRESSING, etc.

DURAWIRE YOUR ELECTRICAL WORK AND BE SURE

4 Distinctive Names for Plastic Insulation

DURATUBE
DURATUBEX
DURAWIRE
DURACABLES

DURATUBE & WIRE, LTD.
FAGGS ROAD, FELTHAM, MIDDLESEX

KING
MINOR ½ TON
MAJOR 2 TONS
MAMMOTH 5 TONS
ELECTRIC CHAIN
PULLEY BLOCK

IN ITS CLASS THIS BLOCK IS THE FINEST MODERN LIFTING DEVICE.

SAFETY LIMIT SWITCH AT TOP AND BOTTOM POSITION PUSH BUTTON CONTROL

●GEO. W. KING LTD. HITCHIN 960
HARTFORD WORKS, HITCHIN, HERTS

CLUTCHES
to the specific requirements of our customers.
COME CLEAN BROTHER!
Makers of all types of repetition products from the bar in all metals.
M.C.L AND REPETITION LTD.
POOL LANE, LANGLEY, BIRMINGHAM.

PAXOLIN
REGISTERED TRADE MARK
ONLY HALF THE WEIGHT OF ALUMINIUM, YET TOUGH AND EASILY MACHINED, "PAXOLIN" LENDS ITSELF TO A MULTITUDE OF MECHANICAL AS WELL AS ELECTRICAL APPLICATIONS.
WRITE FOR PAMPHLET No. PN.1/41
The MICANITE & INSULATORS COMPANY LIMITED
MIC
WALTHAMSTOW LONDON, E.17
Telephone: LARkswood 1044 (Pte. Br. Exch)

WANTED—ELECTRIC MOTORS, GENERATORS and ALTERNATORS of any size and voltage. Machines that require slight overhauling would be entertained. Also Switchgear, Panels, Steam and Diesel Generating Sets, etc. GEORGE COHEN, SONS & CO., LTD., WOOD LANE, LONDON, W.12, and Stanningley, nr. Leeds

FINANCIAL & PARTNERSHIP

WELL-CONNECTED CONCERN is desirous to obtain controlling interest in medium-sized firm manufacturing moulded articles in plastics, preferably in London. Full details to Box No. 5076, c/o "PLASTICS," Bowling Green Lane, London, E.C.1. 71/x9551

MACHINERY, PLANT & TOOLS

SEVERAL BRAND NEW MOTORS, from 1½ h.p. to 5 h.p., 400/440 volts, 3-phase, 50-cycles. THE STERLING PUMP CO., LTD., 29, London Road, Spalding. 71/76

MACHINERY, PLANT & TOOLS WANTED

HYDRAULIC PRESSES WANTED. Send fullest details and prices to Box No. 3697, c/o "PLASTICS," Bowling Green Lane, London, E.C.1. 72/71

OFFICES & BUSINESS PREMISES WANTED

PROGRESSIVE PUBLIC COMPANY open to consider purchase of existing businesses, engaged in Plastics Moulding, on favourable terms. Details to Box No. 7150, c/o "PLASTICS," Bowling Green Lane, London, E.C.1. 73/86

PRODUCTION CAPACITY AVAILABLE

PULVERISING AND GRINDING UNDERTAKEN for the trade, advice given and research undertaken at our experimental stations. DOMEWOOD, LTD., 68, Victoria St., S.W.1. 82/80

SITUATIONS VACANT

ASSISTANT CHEMIST REQUIRED for large works in the North West, moulding Plastics, Bitumastics and Rubber. Experience in all three processes desirable, but particularly in Rubber. Remuneration approx. £350 per annum. Write, stating age and experience, to Box No. 7152, c/o "PLASTICS," Bowling Green Lane, London, E.C.1. 71/83

MAN WITH GENERAL PLASTICS EXPERIENCE for development and to initiate experimental work. Good prospects. West London Factory. Full details of past experience, salary required, to Box No. 7153, c/o "PLASTICS," Bowling Green Lane, London, E.C.1. 71/81

WANTED IMMEDIATELY Chief Foreman for Plywood Press Works. Experienced in operating heavy hydraulic presses. Particulars previous occupation and salary to Box No. 7151, c/o "PLASTICS," Bowling Green Lane, London, E.C.1. 71/85

SITUATIONS VACANT—*contd.*

WORKS MANAGER REQUIRED for new synthetic moulding powder plant—London area. Write full details in first instance to Box No. 4074, FROST-SMITH ADVG., 64, Finsbury Pavement, E.C.2. 71/84

WORKS MANAGER (WORKING) WANTED for small Plastics plant in S.E. England. Must be fully conversant with all branches of the Plastics Industry, able to install the necessary plant and the maintenance of same, and not afraid of hard work. Must be in a position to accept an immediate appointment. Advertiser would be prepared to give the right man an interest in the business. Send full details as to experience and salary required. Box No. 7149, c/o "PLASTICS," Bowling Green Lane, London, E.C.1. 73/87

SITUATIONS WANTED

BAKELITE MOULDING SHOP FOREMAN seeks position. 15 years' practical experience. Excellent references. Box No. 7155, c/o "PLASTICS," Bowling Green Lane, London, E.C.1. 72/x9897

CAMBRIDGE STUDENT of Chemistry—Hungarian—age 21, seeks employment in Laboratory work or to be trained for Process Control. Box No. 5075, c/o "PLASTICS," Bowling Green Lane, London, E.C.1. 71/x9949

PLASTICS TECHNICIAN, young and energetic, experienced all stages laminated moulding, including tool design and manufacture, etc., desires offer. Supervisor or similar. Box No. 5096, c/o "PLASTICS," Bowling Green Lane, London, E.C.1. 71/x9613

MISCELLANEOUS

ACETATE AND NITRATE OFF-CUTS and scrap sheets, also flakes, available for work of National Importance. LLOYDS, 72, Bridge Street, Christchurch. zzz/65

APPROXIMATELY 10 CWT. GREEN BAKELITE POWDER for sale. Full particulars SUNBEAM WORKS, Speke Road, Garston. 71/82

MONOMARK. Permanent confidential London address. Letters redirected. 5/- p.a. Write BM/MONO76, W.C.1. 74/73

7,000 MEMBERS OF THE SCIENTIFIC BOOK CLUB believe that Knowledge is Power. Are you a member? Particulars from 121, Charing Cross Road, London, W.C.2. zzz/66

Printed in England and Published Monthly by the Proprietors, TEMPLE PRESS LTD., BOWLING GREEN LANE, LONDON, E.C.1.

Tullis Russell & Co. Ltd.

MAKERS OF

BODY PAPERS

FOR THE

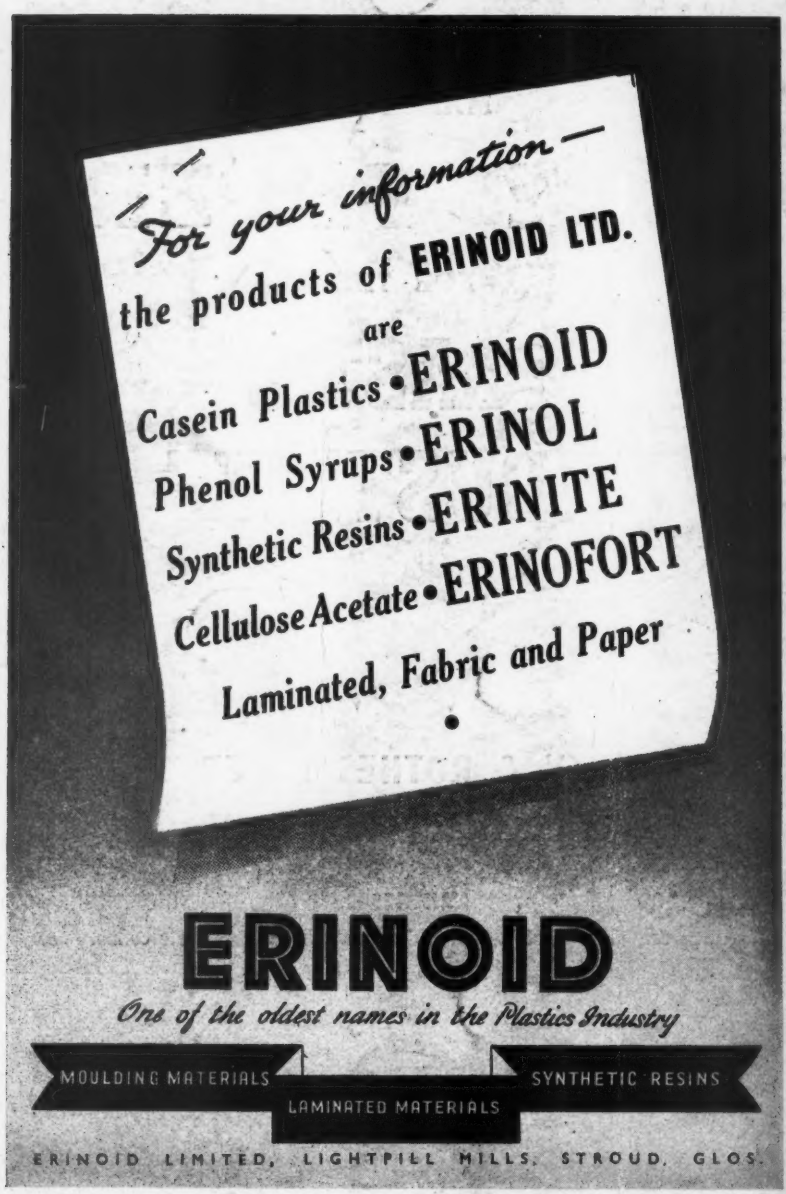
PLASTIC INDUSTRIES

AUCHMUTY & ROTHES PAPER MILLS
MARKINCH, SCOTLAND

LONDON
1 Tudor Street, E.C.4

MANCHESTER
372 Corn Exchange Buildings
Corporation Street

BIRMINGHAM
116 Colmore Row

Reg'd Trade Mark

APRIL, 1943. Vol. VII. No. 71 **Plastics** ONE SHILLING